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ABSTRACT

Results are given for a study of sex differences in high school mathematics achievement and the career consequences of these differences, based on the Project TALENT Data Base. The report contains four separate sections: (1) an Executive Summary; (2) a technical paper focused on sex differences in high school mathematics participation and achievement, targeted for researchers and practitioners, with emphasis on mathematics education; (3) a technical paper focused on the role of high school mathematics achievement in post-high school career development with emphasis on career counseling and occupational attainment, targeted for researchers and practitioners; and (4) a nontechnical booklet targeted for high school girls making decisions regarding elective mathematics courses and for their teachers, counselors, and parents. Among the thirteen findings in the Executive Summary were: at the beginning of high school, boys and girls did not differ significantly in their mean levels of mathematics achievement, but the boys had average gains over twice as large as girls' gains; and the rate of persistence in mathematics related career plans was only 8% for females compared to 18% for males, even though there were no initial sex differences in their mathematics achievement levels. (MK)

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ORIGINS AND CAREER CONSEQUENCES OF SEX DIFFERENCES IN HIGH SCHOOL MATHEMATICS ACHIEVEMENT

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AMERICAN INSTITUTES FOR RESEARCH   JULY, 1979

FOREWORD

The content and organization of this report reflect the approach to dissemination developed early in this project.[*] Rather than a single document, we are submitting four separate documents describing the results of the project for different audiences. The specific documents included are:

- An Executive Summary summarizing the project findings and their implications for policymakers and practitioners interested in a brief overview of the project.
- A technical paper focused on sex differences in mathematics participation and achievement during the high school years, targeted for researchers and practitioners with particular emphasis on mathematics education.
- A technical paper focused on the role of high school mathematics achievement in post-high school career development, targeted for researchers and practitioners, with particular emphasis on career counseling and occupational attainment.
- A nontechnical booklet targeted for high school girls making decisions regarding elective mathematics courses and for the teachers, counselors, and parents who provide advice and guidance for these young women.

The two technical papers were presented at the 1979 annual meeting of the American Educational Research Association and are currently being submitted for publication in research journals. A publisher is also being sought for the booklet to facilitate its dissemination.

The data utilized in these studies were drawn from the Project TALENT data base. Copies of the worktapes containing all the relevant variables can be made available at cost to researchers wishing to investigate further the origins and consequences of sex differences in mathematics achievement.

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[*] The complete dissemination plan was submitted as an attachment to the Quarterly Report prepared in July 1978.

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John Ernest, Elizabeth Fennema, and Jeremy Kilpatrick provided useful suggestions during the planning of this study, although they should not be held responsible for the final results. Their help and guidance are gratefully acknowledged. We are also indebted to members of the Bay Area Math/Science network who reviewed and commented on early drafts of the nontechnical booklet.

Origins and Career Consequences of Sex Differences in High School Mathematics Achievement

EXECUTIVE SUMMARY

A number of studies have identified significant sex differences in mathematics achievement beginning in the junior high school or high school years. The lower level of high school mathematics achievement evidenced by young women has been postulated to be a major barrier leading to the underrepresentation of women in a wide range of professional occupations, most particularly in mathematics, engineering, and the physical sciences. In order to understand more fully the origins and consequences of sex differences in high school mathematics achievement, the National Institute of Education sponsored 10 research projects on this topic beginning in the fall of 1977. This summary describes the results of one of these projects, a study of sex differences in high school mathematics achievement and the career consequences of these differences based on the Project TALENT Data Base.

Approach

This project unvolved secondary analyses of data collected by Project TALENT. These data include a two-day battery of measures of background, cognitive skills, interests, activities, and plans administered to a nationally representative sample of roughly 400,000 high school students in 1960, together with follow-up surveys on subsequent activities and educational and career attainments through age 29.

The project was divided into two phases or studies, each drawing on separate subsets of the TALENT variables and participants. The first study analyzed data on a sample of roughly 1,100 participants who were tested and surveyed as 9th graders in 1960 and then retested and surveyed as 12th graders in 1963. This was a prospective study of 9th grade abilities, interests, activities, plans, and backgrounds that predicted participation in elective mathematics courses and overall mathematics achievement gains during high school. School characteristics and students' activities and development during the high school years were also examined as potential correlates of mathematics participation and achievement.

The second study focused on a sample of roughly 12,000 participants who were tested and surveyed as 12th graders and who were subsequently surveyed or interviewed at ages 19, 23, and 29. The second study examined the importance of high school mathematics achievement for persistence and success in plans to pursue "math-related" careers. In both studies, case weights were used to correct for sampling and attrition biases in estimating national means or proportions.

Findings

The key findings from both studies are listed briefly here, followed by a summary of the significance and implications of these findings. The key findings were:

- At the beginning of high school, boys and girls did not differ significantly in their mean levels of mathematics achievement, but the boys had average gains over twice as large as the girls' gains during the high school years. As a result, by 12th grade very large and significant sex differences in mathematics achievement were evident.
- Virtually all of the sex difference in 12th grade mathematics achievement could be explained by sex differences in participation in elective mathematics courses during high school, although this result was confounded slightly with the fact that females taking elective mathematics were a slightly more select group, as measured by 9th grade achievement, than their male counterparts.
- Interest in mathematics and math-related careers further predicted math achievement gains after level of participation was controlled. The very large sex differences in career interests explained the remaining sex differences in 12th grade achievement after 9th grade achievement and level of participation were controlled.
- The most significant predictors of participation in elective mathematics courses were 9th grade abilities and educational aspirations. However, since males and females did not differ greatly on these variables, they could not account for much of the sex difference in participation.

- The level of interest in math-related careers was the next most significant predictor of mathematics participation after abilities and educational aspirations were controlled. The large sex differences in interest in math-related careers did account for most of the sex difference in participation.

- A general measure of self-confidence and the characteristics of their fathers were further predictors of math participation for females but not for males. On the other hand, spatial abilities further predicted math participation for males but not for females.

- While much of the effect of school programs on math participation was confounded by correlations between student and school characteristics, the availability of an accelerated science curriculum was significantly related to 12th grade mathematics achievement for females after controlling for 9th grade characteristics. The availability of an accelerated science curriculum was also correlated with a decrease in female interest in office work between grades 9 and 12.

- The frequency of standardized testing in the schools was related to increased participation in mathematics, particularly for females.

- Careers requiring college mathematics were highly selective in that fewer than one in six high school seniors planning these careers persisted in those plans through age 29, and fewer than 3% not planning such careers were later successful in switching into these careers.

- High school mathematics achievement was found to be significantly related to persistence in math-related career plans. Students planning such careers had average math achievement scores at the 75th percentile, but those who persisted and had entered a math-related career by age 29 had had math achievement scores averaging at the 90th percentile in 12th grade.

- The rate of persistence in math-related career plans was only 8% for females compared to 18% for males, even though there were no initial sex difference in the math achievement level of those planning a math-related career.
- The largest component of the effect of high school mathematics achievement on the mathematics level of occupation at age 29 was through its effect on persistence in plans to complete a math-related college major. However, high school mathematics achievement predicted persistence in math-related career plans at each stage even after the math level of the college major and the level of education completed were controlled.
- Sex differences in the math level of occupation at age 29 were accounted for by a combination of sex differences in high school career plans and mathematics achievement.

Summary and Implications

The results of this project confirm the hypothesis that high school mathematics achievement is critical to the development of a range of important professional careers and that the lower levels of high school mathematics achievement evidenced by females effectively closes out any future options to enter these careers. This is not to say that high school mathematics is the only barrier to full female participation in math-related careers. The significantly lower rates of persistence in a math-related career path for females who do have the plans and abilities clearly warrants further study. A combination of career interests and mathematics achievement do, however, account for a large segment of the sex differences in the development of math-related careers.

The findings suggest that increasing female participation in elective mathematics courses could effectively remove the sex differences in high school math achievement. Increasing young women's awareness of and interest in math-related careers is one step that would be likely to lead to increased participation. It is probable, for example, that an accelerated science curriculum led to greater levels of achievement for females largely because they were more likely to perceive the usefulness of mathematics in interesting careers.

The issue of self-confidence was only touched on briefly in this report, largely because there were no available measures of confidence in mathematics abilities. It is significant, however, that the very general measure of self-confidence used in this study was related to female mathematics participation. It is possible that the observed effect of frequent standardized testing was related to students' increased awareness of and hence confidence in their level of abilities.

It is not clear that young women and men who fail to take elective mathematics courses realize the likely limitations to their subsequent career options. The effective dissemination of the findings from this and the other NIE-sponsored projects could go a long way toward increasing the degree to which informed decisions are made regarding high school mathematics.

ORIGINS OF SEX DIFFERENCES IN HIGH SCHOOL MATHEMATICS ACHIEVEMENT AND PARTICIPATION

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ORIGINS OF SEX DIFFERENCES IN HIGH SCHOOL MATHEMATICS ACHIEVEMENT AND PARTICIPATION

Although women start out with mathematics abilities comparable to those of men, by adulthood clear sex differences have emerged in the levels of mathematics achievement (Maccoby and Jacklin, 1974). Data compiled by the College Board (Educational Testing Service, 1974a, 1974b, 1974c, 1975, 1975-76, 1977, 1978) indicate that for the past six years women's scores on the Scholastic Aptitude Test have averaged .5 standard deviations below men's scores. Similar differences between college-bound men and women in participation in math courses in high school and in plans for mathematics-related careers during that period were also reported. Because insufficient mathematics training and achievement have been postulated as two of the major barriers to women's pursuit of mathematics-related careers (Astin, 1970; Rever, 1973; Sells, 1973), it is important that the forces resulting in these sex differences in mathematics participation and achievement be identified and dealt with.

The present study is a detailed examination of factors that contribute to sex differences in mathematics participation and achievement.* The study uses data from Project TALENT, a massive nationwide longitudinal study of approximately 400,000 young men and women who were in high school in 1960, to investigate the antecedents of decisions to take elective math courses in high school and the effect of these decisions on math achievement gains during high school. The following questions are addressed:

1. To what extent were sex differences in math achievement evident during the high school years?
2. To what extent could sex differences in math achievement during high school be attributed to sex differences in participation in elective math courses?

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* A companion study examined the importance of high school mathematics achievement for subsequent development in mathematics-related careers. Further information on this study is provided by Wise (1979).

3. To what extent could sex differences in math participation and achievement during high school be accounted for by differences in abilities, interests, and plans already evident in ninth grade? by differences in school environments?

Background

Sex-related differences in math achievement have been reported again and again in the research literature. Some researchers have called the differences "overwhelming" (Mullis, 1975), while others have described them as "minimal" (Fennema and Sherman, 1977a). The latter have suggested that there may be no real sex differences in math aptitude, and that many of the reported differences in achievement result from a failure to control for the number and nature of math courses taken by students in the various studies.

Several of the findings, however, suggest differences that are too large to dismiss without further investigation. In an analysis of data on students from the Educational Testing Service Growth Study, Hilton and Berglund (1974) found significant sex differences in math achievement favoring males. These differences began for academic students in Grade 7 and for nonacademic students in Grade 11.

One of the most frequently suggested contributors to sex differences in math achievement is the sex role socialization of males and females. The major research in this area has been summarized by Fox (1976). Mathematics has often been described as a "male domain" (Aiken, 1975; Astin, 1974; Fennema and Sherman, 1977a). Precisely when and where such stereotyping begins is a matter of debate. Stein and Smithells (1969) gave evidence that students did not consider math a "masculine" subject until they reached adolescence. Fennema (1976) found that female high school students denied that math was a sex-stereotyped subject, yet behaved as though math were for males by their avoidance of elective math courses. Horner (1972) suggested that females were motivated to avoid success in traditionally "male" areas such as math. Aiken (1975, 1976) suggested that sex differences in math ability were partially a consequence of same-sex modeling by girls, who had few female role models for success in mathematics, and Maccoby and Jacklin (1974) concluded that same-sex models were the most potent for stimulating imitative behavior; hence, girls tended to imitate their verbally-oriented mothers, while boys emulated their quantitatively-oriented fathers.

A related factor that may underlie sex differences in math achievement is the perceived usefulness of math for later careers, which Haven (1972) found to be one of the most significant predictors of decisions by gifted high school girls to take or not take elective math courses. Haven found the girls less likely than their male counterparts to perceive math as relevant to their career goals. Fennema and Sherman (1977b) also found that the perceived usefulness of math was related to the election of math courses. In addition, they found significant sex differences in achievement in schools where there were also significant sex differences in the perceived usefulness of math. These differences in perceived usefulness may reflect the different career orientations of males and females (Fox, 1976) or they may result from a lack of sufficient information. Fennema and Sherman (1977b) suggested that girls were unaware that mathematics was relevant to many careers besides purely scientific ones.

Conceptual Framework of the Study

Based on this existing base of research, mathematics achievement in high school is viewed as resulting primarily from initial mathematics aptitudes and participation in high school mathematics courses. Math participation, in turn, is considered to be determined by individuals' family background, cognitive abilities, social-psychological attributes (e.g., attitudes, plans, expectations) and characteristics of the school environment. The relationships between these various factors are depicted in Figure 1. It is hypothesized that

1. sex differences in high school math achievement will be explained primarily by sex differences in participation in high school math courses, and
2. sex differences in math participation will be explained primarily by sex differences in social-psychological characteristics (e.g., interests, aspirations, plans).

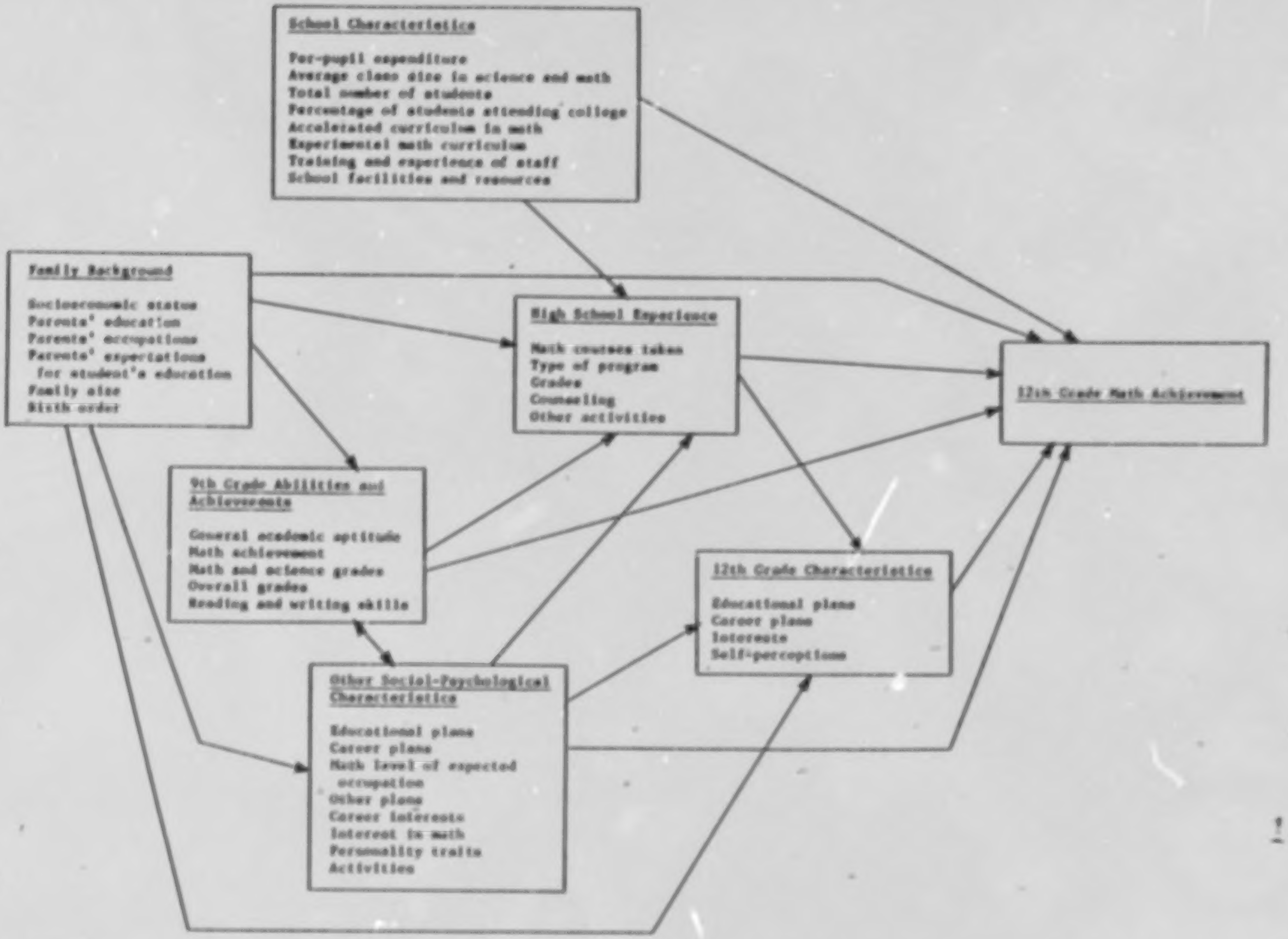
School Characteristics
Per-pupil expenditure
Average class size in science and math
Total number of students
Percentage of students attending college
Accelerated curriculum in math
Experimental math curriculum
Training and experience of staff
School facilities and resources
Family Background
Socioeconomic status
Parents' education
Parents' occupations
Parents' expectations for student's education
Family size
Birth order
High School Experience
Math courses taken
Type of program
Grades
Counseling
Other activities
12th Grade Math Achievement
9th Grade Abilities and Achievements
General academic aptitude
Math achievement
Math and science grades
Overall grades
Reading and writing skills
12th Grade Characteristics
Educational plans
Career plans
Interests
Self-perceptions
Other Social-Psychological Characteristics
Educational plans
Career plans
Math level of expected occupation
Other plans
Career interests
Interest in math
Personality traits
Activities

Figure 1. Conceptual framework of study

Procedures

Sample

The present study used data on a subset of the 1960 TALENT participants who were tested and surveyed both in 1960 (as 9th graders) and in 1963 (as 12th graders) to examine factors influencing math gains during high school. The procedures used to select the original sample of TALENT participants are described in detail in Chapter 2 of The Project TALENT Data Bank Handbook (Wise, McLaughlin, and Steel, 1977). Briefly, a cluster sampling approach was used with American high schools as the primary sampling unit. All American high schools were stratified by geographic region (8 USOE regions with the 5 largest cities treated separately), by type of school (private, parochial, or public with the public schools divided into 4 groups based on enrollment) and by retention ratio (the ratio of graduates to 10th graders). Within each of the cells thus defined, schools were selected randomly, with 1/13 of the large public schools, 1/50 of the very small public schools, and 1/20 of all other schools being chosen. Approximately 93% of the schools so chosen agreed to participate in the study. All of the students in each of the 987 participating schools were included in the TALENT probability sample, a total of over 375,000 students. (Approximately 65,000 additional students in special supplemental samples were also tested.)

The analyses reported here are based on a special sample of roughly 7,500 9th grade students in 1960 who were retested as 12th graders in 1963. In selecting the retest sample, all of the 1960 TALENT schools were sorted into groups based on type of school (public vocational, public nonvocational, nonpublic). The public nonvocational schools were further sorted by city size (6 levels) with the schools from large and very large cities sorted on "economic level" and the others sorted further on region. Schools were then sampled from each of the "public school" cells in this taxonomy. In all, 118 public high schools drawn from all geographic regions and economic strata participated in the study, with all of the seniors in each school included in the retest sample. Roughly 75% of those tested were found to have been tested in 1960, the other 25% being transfers or accelerated students.

In order to shorten the time required for testing in the 1963 retest, seven different and overlapping test batteries were used, each containing about half of the 1960 test material. The composition of each of the batteries is shown in Table 1. For purposes of the proposed study, Battery D is of primary interest since it contains both student background information (including math courses taken) and scores on the math information and ability tests. Approximately 1,100 of the students tested in 1960 completed Battery D. This sample includes students from nearly all of the public school categories in the school taxonomy. Data collected with Batteries A and E were also used in analyses focusing on math participation only. A complete description of the 1963 retest study including the sample design, the instruments used, a discussion of the reliabilities of these instruments, and general findings of the study is given in The High School Years: Growth in Cognitive Skills (Shaycoft, 1967).

Study Variables

The analyses for this study were based on data collected from TALENT participants and schools in 1960 and again in 1963. These data include students' family backgrounds, their cognitive abilities and achievements, their interests, aspirations, and plans, and various personality characteristics. Data on the characteristics of the schools were also obtained. The Project TALENT Bank Handbook (Wise, McLaughlin, and Steel, 1977) includes a description of each of the instruments in the 1960 and 1963 test batteries and reproductions of each of the questionnaires except for the 1963 Student Information Blank.

As indicated in Figure 1, the dependent variables of interest here were math achievement, as measured in 12th grade, and level of participation in high school math classes. These variables were measured as follows.

Math achievement. The math achievement measure used in this study was the individual's score on a 54-item test including 16 "word problem" items designed to measure arithmetic reasoning, 24 introductory math items primarily covering elementary algebra and number theory, and 14 advanced math items covering topics generally taught in grades 10 through 12 including plane geometry, analytic geometry, trigonometry, and elementary calculus.

Math participation. The measure of math participation used was the number of math courses marked in the 1963 Student Information Blank. The list included first-year algebra, plane geometry, second-year algebra, solid geometry, trigonometry, and analytic geometry or calculus. Scores on

TABLE 1

Composition of the Seven Retest Batteries (Spring 1963)

Test Code #	Test	Battery						
190	Information I	A	B	C				V
192	Information II	A			D	E		
211	Memory for Sentences*							
212	Memory for Words		B		D		F	
220	Disguised Words			C		E	F	
230	English		B		D		F	V
240	Word Functions in Sentences			C		E	F	
250	Reading Comprehension			C		E	F	V
260	Creativity			C		E	F	V
270	Mechanical Reasoning			C		E	F	V
281	Visualization in Two Dimensions			C		E	F	
282	Visualization in Three Dimensions			C		E	F	V
290	Abstract Reasoning	A	B	C	D	E	F	V
311	Math I. Arithmetic Reasoning		B		D		F	V
312	Math II. Introductory H.S. Math		B		D		F	
333	Math III. Advanced H.S. Math		B		D		F	
410	Arithmetic Computation		B		D		F	V
420	Table Reading			C		E	F	
430	Clerical Checking			C		E	F	V
440	Object Inspection			C		E	F	V
500	Preferences*							
600	Student Activities Inventory*							
700	Interest Inventory	A			D	E		
800'	Revised Student Information Blank	A			D	E		
Themes								
	"My Views about an Ideal Occupation"	A			D	E		
	Theme on help received from testing and counseling	A			D	E		

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*Not included in any retest battery

NOTE: From The High School Years: Growth in Cognitive Skills (Shaycoft, 1967, p C-3) this measure ranged from 0 to 6. This measure was found to have higher predictive validity than an alternative measure of math participation based on the "highest level" course marked.

As shown in Figure 1, several variables besides sex were also hypothesized to influence high school math participation and/or achievement. These include individuals' family background, their various cognitive and social-psychological attributes in 9th grade and in 12th grade, their experiences during high school, and several characteristics of the schools themselves. Most of these variables were assessed directly in the 1960 and/or 1963 TALENT tests and questionnaires. However, three variables which were of considerable theoretical interest were not assessed directly but, rather, derived from the data available.

Math level of expected occupation. Some initial analyses were done in defining the math level of individuals' career plans. Three indicators of the amount of college and high school math typically taken by those in each career were developed. Table 2 shows these indicators and the resultant classification of careers into 6 levels of math. Careers at levels 4, 5, and 6 mostly require some college math and so are grouped together and labeled "math-related" careers in some analyses. Careers at level 3 generally require college participation and may require some statistics but do not require calculus or other college math. They are used as an "intermediate" level in many analyses to provide a comparison group with a level of education somewhat comparable to the "math-related careers." Level 1 and 2 careers are grouped together as low math-level careers in many of the analyses.

Math level of expected college majors. College majors were classified into the same 6 math levels used in classifying careers. The 6 levels were collapsed into three groups, math-related, intermediate math level, and low math level, analogously to the career categories.

Interest in math and math-related careers. A 205-item interest inventory with 17 scales was administered in 1960 and 1963. The primary scales used in the present study were "Physical Science, Math, and Engineering Interest" and "Interest in Office Work." In addition, four items relating specifically to mathematics were combined to form a measure of interest in math itself.

TABLE 2

The Math Level of Careers as Defined by Three Required Math Education Indicators

Career Plan (No. of cases) (1-year Follow-Up)	Indicator College Math (% in 1st year math & earning high grades)	 College Math (% taking or planning to take college math)	 High School Math (% taking more than 2 years)
Level 6:			
Mathematician (86)	88	92	92
	*		
Level 5:			
Engineer (682)	76	87	90
Physical Scientist (186)	75	90	92
Architect (73)	71	88	77
Pilot (13)	69	92	85
	*		
Level 4:			
Pharmacist (70)	65	87	80
Dentist (68)	63	79	87
Physician (264)	61	87	89
Biological Scientist (109)	59	86	75
Armed Forces Officer (38)	59	72	87
	*		
Level 3:			
Forester (38)	45	68	61
Lawyer (183)	43	67	84
College Professor (73)	48	62	77
Engineering Aide (15)	43	57	67
Medical/Dental Technician (145)	40	58	50
Accountant (402)	40	48	55
High School Teacher (1427)	39	57	62
Elementary Teacher (587)	40	57	54
Sociologist/Psychologist (97)	34	70	68
Political Scientist/Economist (80)	32	68	74
Businessman (398)	33	51	58
Librarian (22)	36	55	59
Clergyman (106)	34	49	55
Writer (94)	26	65	62
Social Worker (95)	25	46	67
		*	
Level 2:			
Nurse (490)	7	9	50
Salesperson (97)	22	31	51
Policeman/Fireman (58)	4	19	61
Armed Forces Enlistedman (73)	15	29	51
Artist/Entertainer (160)	6	23	41
Farmer (187)	18	31	34
Skilled Worker (418)	10	12	49
Structural Worker (82)	12	15	38
			*
Level 1:			
Secretary/Office Worker (972)	6	8	17
Barber/Beautician (173)	1	1	14

* Denotes gap in indicator values that were used in defining the 6 levels.

Results

Several analyses were performed to determine the antecedents of sex differences in high school math participation and achievement. First, the first-order relationships of each of the variables to the two primary variables--math participation and grade 12 math achievement--were determined. These results served to focus attention on the independent variables with the most significant relationships to math participation and achievement. They also provide an assessment of sex differences in the independent variables that might be predictive of the sex differences in the primary outcome variables.

After the first-order analyses were completed, higher-order analyses, primarily regression analyses and analyses of covariance, were used to investigate the interactions between the study variables that were predictive of math participation and achievement. These higher-order analyses addressed the following research questions:

1. To what extent were sex differences in math achievement evident during high school?
2. To what extent can sex differences in math achievement gains be attributed to differential rates of participation in elective math courses?
3. What other factors "predict" gains in math achievement?
4. What factors predict math participation and to what extent do sex differences in these factors account for sex differences in math participation?
5. Are there characteristics of schools and school environments that affect math participation after controlling for initial student characteristics?
6. What high school experiences and 12th grade characteristics typified students with higher than expected levels of math participation and achievement?

Based on the results obtained, structural equation models of the relationships between sex and math participation and achievement were estimated and tested.

First-Order Relationships to Math Participation and Achievement

The data analyses began with an examination of the direct relationship of each variable of interest to the outcome variables of primary concern, the amount of math taken in high school (math participation) and 12th grade math achievement. Table 3 lists the variables for which correlations of .20 or more were found. As can be seen, a large number of variables had correlations of at least .20 with either math participation or 12th grade math achievement. Most of the variables that were correlated strongly with math participation also tended to be strongly related to 12th grade math achievement. Moreover, with the exception of variables relating to sex stereotypy (e.g., participation in male- or female-stereotyped activities, interest in male- or female-stereotyped careers), the direction of the relationships found tended to be consistent for both sexes. Finally, although many of the variables strongly related to math participation and achievement for women also tended to be highly correlated with men's achievement and participation, several clear sex differences can be seen in the strength of the relationships found.

Table 4 shows the extent of sex differences on some of the more significant background and 9th grade characteristics variables. These factors which show significant sex differences and which also show significant relationships to the outcome variables are of particular importance, since reducing the sex differences in these predictor variables may lead to reduced sex differences in the outcome variables.

These results provided an initial estimate of the relative importance of different factors in determining math participation and achievement, and they were used to guide the order in which potential predictors and correlates were further investigated. However, it must be remembered that these relationships themselves do not imply causality but rather serve as reference points that must be matched by underlying causal models.

Extent of Sex Differences in Math Achievement During the High School Years

Figure 2 shows the mean math achievement scores, based on the TALENT 1960 tests, for males and females in each high school grade. The difference in the male and female means among 9th graders, while statistically significant because of the very large sample size, was less than .07 standard deviation, which was too small to be of much practical significance. (The results in

TABLE 3

Summary of the Significant First-Order Relationships Between Study Variables and the Amount of Math Participation and Achievement*

	Correlations With:			
	Math Taken		12th Grade Achievement	
	M	F	M	F
Background Variables				
Father's Level of Education (ASIB218)	.21	.31	.23	.30
Mother's Level of Education (ASIB219)	.18	.24	.21	.24
Socioeconomic Status (P801)	.31	.41	.35	.42
Birth Order (BIRORD)	-.14	-.18	-.26	-.18
Father's Occupational Prestige (FOCCPRS)	.07	.22	.01	.15
Math Level of Father's Occupation (FOCCMTH)	.09	.21	.02	.14
Family Size (ASIB221)	-.14	-.19	-.16	-.20
9th Grade Characteristics				
Ability Measures				
Math Achievement (AMTHTOT)	.61	.63	.77	.79
General Academic Abilities (C002)	.60	.59	.78	.77
9th Grade Math Grades (ASIB106)	.33	.42	.39	.52
9th Grade Science Grades (ASIB107)	.38	.43	.38	.45
9th Grade Grades, All Subjects (P820)	.41	.52	.44	.56
Self-Perception of Reading Skills (P829)	.27	.32	.29	.33
Self-Perception of Writing Skills (P828)	.23	.23	.21	.24
Educational Plans				
Amount of Education Expected (ASIB304)	.50	.57	.45	.49
Type of High School Program (D802)	.44	.54	.43	.48
Parents' Expectations (ASIB337)	.28	.48	.35	.40
Importance of Father's Expectations (ASIB308)	.25	.38	.16	.28
Importance of Mother's Expectations (ASIB309)	.26	.36	.15	.27
Importance of Teacher's Expectations (ASIB314)	.20	.23	.07	.18
Importance of Friends Not Going to College (ASIB331)	-.24	-.11	-.28	-.13
Discussed Plans with Father (ASIB122)	.14	.29	.17	.23
Discussed Plans with Mother (ASIB123)	.14	.22	.17	.18
Importance of College for Girls (ASIB334)	-.04	-.22	-.12	-.21

---

*Based on 643 females and 567 males in the 1963 retest sample for whom 12th grade questionnaire and math achievement data were both available.

TABLE 3 (cont.)

	Correlations With:			
	Math Taken		12th Grade Achievement	
	M	F	M	F
Career Plans				
Importance of College for Career (ASIB307)	.43	.37	.37	.31
Math Level of Expected Career (AOCCMAE)	.25	.37	.27	.31
Math Level of Desired Career (AOCCMAD)	.25	.35	.29	.33
Importance of Getting a Job as Soon as Possible (ASIB320)	-.11	-.20	-.10	-.24
Importance of College for Learning About Careers (ASIB311)	.21	.21	.14	.12
Importance of College for Earnings (ASIB310)	.31	.21	.21	.14
Other Plans				
Importance of Marriage over College (ASIB324)	-.22	-.14	-.23	-.10
Expected Number of Children (ASIB362)	.12	.24	.10	.23
Interests				
Interest in Math (AMTHINT)	.44	.36	.43	.37
Interest in Physical Science, Engineering, and Math Careers (P701)	.36	.35	.35	.31
Interest in Office Work (P713)	-.04	-.26	-.09	-.23
Interest in Skilled Trades (P715)	-.23	-.05	-.26	-.06
Interest in Labor Careers (P717)	-.20	-.10	-.22	-.11
Activities				
Study Habits (F827)	.32	.34	.32	.36
Extracurricular Reading (F830)	.19	.24	.16	.30
Variety of Extracurricular Activities (F831)	-.03	.06	-.24	-.05
Participation in Male-Stereotyped Activities (AMALACT)	-.03	-.03	-.12	-.07
Participation in Female-Stereotyped Activities (AFEMACT)	-.08	.05	-.27	.07
Predominance of Male-Stereotyped Activities (ASXSACT)	.05	-.08	.11	-.11
Traits				
Mature Personality (R610)	.25	.25	.25	.26
Tidiness (R606)	.24	.14	.20	.13
Calmness (R605)	.22	.18	.22	.21
Self-Confidence (R609)	.20	.10	.22	.18
Enjoy Learning (ASIB313)	.13	.31	.11	.24

TABLE 3 (cont.)

	Correlations With:			
	Math Taken		12th Grade Achievement	
	M	F	M	F
High School Experiences				
Courses Taken				
Amount of Math Taken (MATHTKN)	1.00	1.00	.71	.74
Number of Business or Commercial Courses (BSIB111)	-.35	-.47	-.28	-.32
Number of Science Courses Taken (SCITKN)	.42	.40	.35	.28
High School Program (BSIB052)	.60*	.67*	.54*	.57*
Grades				
Math Grades (BSIB114)	.28	.36	.38	.45
Science Grades (BSIB115)	.28	.36	.33	.38
All Grades (BSIB121)	.31	.38	.30	.40
Counseling				
Discussed Plans with Teachers or Counselors (CONCNCL)	.37	.45	.33	.39
Discussed Plans with Others (CNCLOTH)	.24	.34	.23	.30
Activities				
Number of Leadership Roles (LDRSHP)	.14	.28	.11	.26
Hours Studied Each Week	.21	.20	.21	.20
12th Grade Characteristics				
Educational Plans				
Amount of Education Expected (BSIB064)	.57	.60	.52	.54
Expect to Attend College (BSIB059)	.57	.60	.51	.52
Plan to Attend 4-Year, 2-Year, More (BSIB060)	.51	.58	.50	.51
Plan to Attend Full-Time (BSIB062)	.50	.53	.48	.46
Saving for College (BSIB186)	.48*	.48*	.45*	.44*
Plan to Attend Business or Commercial School (BSIB058)	-.28	-.30	-.26	-.29
Plan to Attend Vocational School (BSIB057)	-.28	-.16	-.30	-.23
Math Level of Expected Major (BMTHMAJ)	.51		.50	
Type of College (BSIB220)	.57*	.59*	.59*	.55*
Major (BSIB209)	.53*	.65*	.52*	.58*
Expected College Costs (BSIB169)	.15	.21	.09	.11
When College Expected (BSIB061)	.51*	.61*	.49*	.55*

---

*Eta is shown for categorical variables.

TABLE 3 (cont.)

	Correlations With:			
	Math Taken		12th Grade Achievement	
	M	F	M	F
Career Plans				
Math Level of Planned Career (BOCCMTH)	.38	.34	.37	.30
Prestige of Planned Career (BOCCPRS)	.36	.38	.35	.33
Number of Occupations Considered (BSIB240)		.10	.20	.12
Financial Aspirations (BFINASP)	.21	.14	.23	.12
Interests				
Interest in Math (BMTHINT)	.40	.40	.44	.46
Interest in Physical Science, Engineering, or Math Career (BP701)	.35	.41	.40	.47
Interest in Biological Science or Medical Career (BP702)	.24	.30	.27	.30
Interest in Office Work (BP713)	.01	-.40	-.03	-.32
Interest in Skilled Trades (BP715)	-.23	-.07	-.23	-.06
Interest in Female-Stereotyped Careers (BFEMINT)	.04	-.23	.02	-.19
Interest in Male-Stereotyped Careers (BMALINT)	-.06	.17	-.03	.20
Predominance of Interest in Female-Stereotyped Careers (BSXSINT)	.08	-.30	.01	-.29
Self-Perceptions				
How Do You Compare on Intelligence? (BSIB208)	.27	.32	.33	.33
Do You Have a Good Idea of Your IQ? (BSIB214)	.17	.24	.13	.18
School Characteristics				
Daily % Absenteeism (GSC29)	-.02	-.04	-.27	-.28
% in a College Prep Program (GSC62)	.12	.05	.31	.24
Honors Courses in Math (GSC14/1)	.17	.17	.25	.22
Number of Full-Time Teachers (GSC43)	.01	.09	.24	.25
Number of Books in Library (GSC32)	-.10	.12	.11	.24
Number of Extracurricular Activities Available (EXTACTIV)	.06	.15	.18	.21
Training and Experience of Staff	.17	.17	.26	.20
Large-Scale Intersystem Math Tryout (GSC25)	.08	.02	.16	.12
% Taking New Work in Summer (GSC81)	.06	.01	.17	.13
Variety of Community Facilities Available	.01	.06	.15	.20

---

*Eta is shown for categorical variables.

TABLE 4

Sex Differences in Selected 9th Grade Characteristic and Background Variables

Variables	Means Male	 Female	t	Significance Level
Knowledge and Ability Measures				
9th Grade Math Achievement	20.73	20.92	-.46	.65
Arithmetic Reasoning	8.09	8.05	.19	.85
Introductory Math	10.24	10.62	-1.67	.10
Advanced Math	2.37	2.24	1.53	.13
Math Information	7.66	7.10	2.67	.008
General Academic Aptitude	470.59	493.89	-3.90	< .001
Vocabulary	12.11	10.77	6.28	< .001
Music	5.31	6.14	-5.21	< .001
Social Studies	14.55	12.77	6.28	< .001
Physical Science	9.72	7.80	9.64	< .001
Biological Science	6.18	5.28	7.09	< .001
Aeronautics & Space	4.57	2.76	16.03	< .001
Electricity & Electronics	9.13	5.83	17.04	< .001
Mechanics	11.37	7.45	22.38	< .001
Farming	7.83	7.31	3.87	< .001
Home Economics	7.65	11.73	-22.98	< .001
Sports	7.59	5.37	14.78	< .001
Law	4.62	4.10	5.21	< .001
Medicine/Health	5.29	5.62	-2.82	.005
Engineering	3.04	2.46	1.04	< .001
Foreign Travel	2.51	2.11	5.38	< .001
Military	2.16	1.70	6.35	< .001
Clerical	1.17	1.47	-6.18	< .001
Memory for Sentences	8.94	9.93	-5.73	< .001
Memory for Words	10.52	12.17	-5.48	< .001
Disguised Words	12.76	14.19	-3.87	< .001
English Total	76.80	82.86	-8.26	< .001
Word Functions in Sentences	8.57	10.67	-7.11	< .001
Reading Comprehension	26.76	28.93	-3.80	< .001
Mechanical Reasoning	11.72	8.65	14.77	< .001
Visualization in 2 Dimensions	12.93	11.54	4.31	< .001
Visualization in 3 Dimensions	8.57	7.84	4.19	< .001
Arithmetic Computation	24.47	30.90	-6.02	< .001
Table Reading	7.43	9.15	-3.86	< .001
Clerical Checking	20.12	24.79	-4.25	< .001
Object Inspection	19.29	21.42	-4.70	< .001
Interest Measures				
Math Interest	28.52	23.93	7.17	< .001
Male Stereotyped Areas	31.37	18.05	36.12	< .001
Female Stereotyped Areas	19.50	36.94	-45.61	< .001
Overall Sex Stereotyping in Interests	52.84	-22.11	67.96	< .001

TABLE 4 (cont.)

Variables	Means			Significance
	Male	Female	t	Level
Physical Sciences	21.54	12.24	20.91	< .001
Biological Sci., Medicine	18.74	16.03	4.81	< .001
Public Service	18.55	11.66	10.46	< .001
Literary-Linguistic	15.70	20.55	-9.92	< .001
Social Service	16.02	23.78	-18.31	< .001
Artistic	15.94	20.11	-7.55	< .001
Musical	12.88	17.46	-7.20	< .001
Sports	27.64	18.97	15.37	< .001
Outdoor Recreation	27.16	13.79	20.81	< .001
Business Management	19.43	15.04	9.98	< .001
Sales	16.71	13.05	7.29	< .001
Office Work	12.61	22.83	-20.11	< .001
Mechanical-Technical	19.90	7.47	31.41	< .001
Skilled Trades	12.74	8.19	12.64	< .001
Farming	20.56	13.25	13.17	< .001
Labor	11.75	7.37	11.75	< .001
Personal Traits				
Sociability	6.28	6.77	-2.90	.004
Social Sensitivity	3.70	4.58	-6.52	< .001
Tidiness	4.92	5.72	-5.05	< .001
Culture	4.40	5.40	-7.51	< .001
Activities				
High School Courses Taken	21.30	18.92	4.77	< .001
High School Grades	26.32	29.20	-4.68	< .001
Guidance Received in High School	18.12	15.58	2.77	.006
Guidance Received Elsewhere	11.89	13.48	-4.12	< .001
Study Habits & Attitudes	24.07	27.24	-10.34	< .001
Self-perception of Writing Skills	21.21	24.26	-6.51	< .001
Amt. of Extracurricular Reading	32.67	37.00	-3.61	< .001
Degree of Participation in Extra-curricular Sports	17.97	20.11	-2.43	.015
Variety of Hobbies	64.40	55.18	8.22	< .001
Participation in Sports	16.64	13.63	10.04	< .001
Social Life	40.94	38.47	2.24	.016
Work Activities	16.34	13.15	8.53	< .001
Male Stereotyped Activities	31.98	18.54	35.43	< .001
Female Stereotyped Activities	20.30	35.49	-36.00	< .001
Overall Stereotyping of Activities	62.70	34.05	58.67	< .001
Expected Level of Education	4.18	3.95	2.51	.012

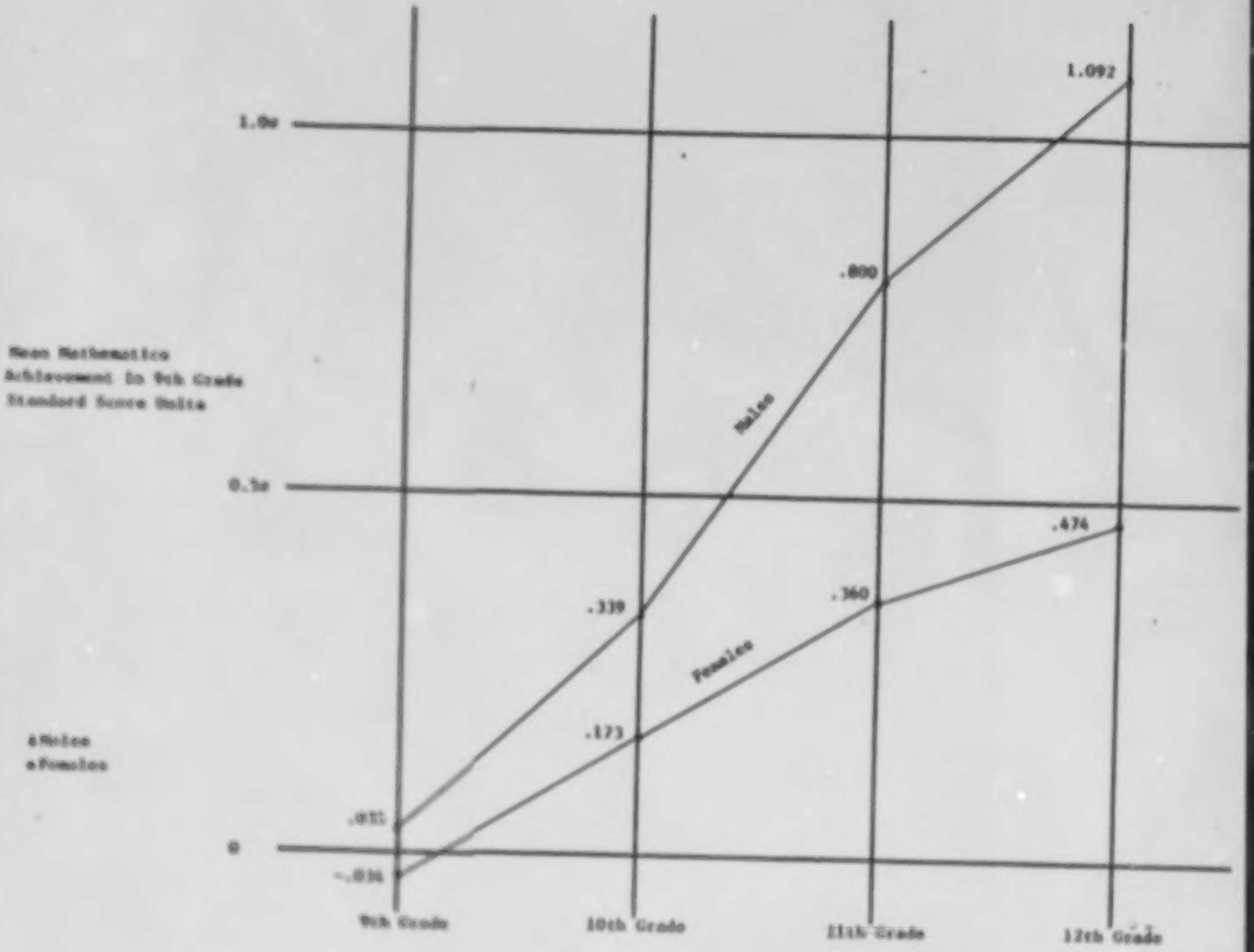

Figure 2. Comparison of Mathematics Achievement Gains of Males and Females

Figure 2 were based on a 10% sample of all TALENT 1960 cases containing just under 5,000 cases for each sex and grade. The appropriate t statistic was 6.8.) The male gains in math achievement during high school were more than twice the female gains. Sex differences in math achievement increased most sharply after the 10th grade, the time at which mathematics courses became truly elective.

Figure 2 presents cross-sectional data. Some of the "gain" in math achievement could well be due to differential dropout rates with respect to math scores. However, almost exactly the same results were obtained from the sample of roughly 3,500 cases who were given the math achievement test in both the 9th and 12th grades.

Figure 3 shows how changes from grade 9 to grade 12 based on the same retest participants compare with the differences between the separate 9th and 12th grade 1960 samples. The scores for the females in the retest sample were slightly higher than the female scores in the complete 1960 9th grade sample, which may be due to differences between transfers and non-transfers or because of normal sampling error in the selection of retest schools. Nonetheless the differences are quite small relative to the 12th grade sex differences, and the pattern of gains for the retest cases is virtually identical to the cross-sectional "gains" measured in 1960.

While the differences between the entire TALENT sample and the 1963 retest sample are slight, the sex differences are striking. There are no significant differences in the 9th grade, but males showed an average achievement gain of over one standard deviation relative to the 9th grade distribution, while females gained only half as much. Figure 2 suggests that these differences are sharpest after the 10th grade, which, perhaps not coincidentally, is when math courses generally become truly elective.

Relationship Between Sex Differences in Math Participation and Sex Differences in Math Achievement

The two strongest predictors of 12th grade math achievement were 9th grade math achievement (r = .78) and the amount of math taken in high school (r = .73). Ninth grade math achievement is, indeed, a powerful predictor, as higher 9th grade scores were associated with higher raw gain scores, so that individual differences tended not only to remain consistent, but actually tended to increase. (The opposite was true for other measures,

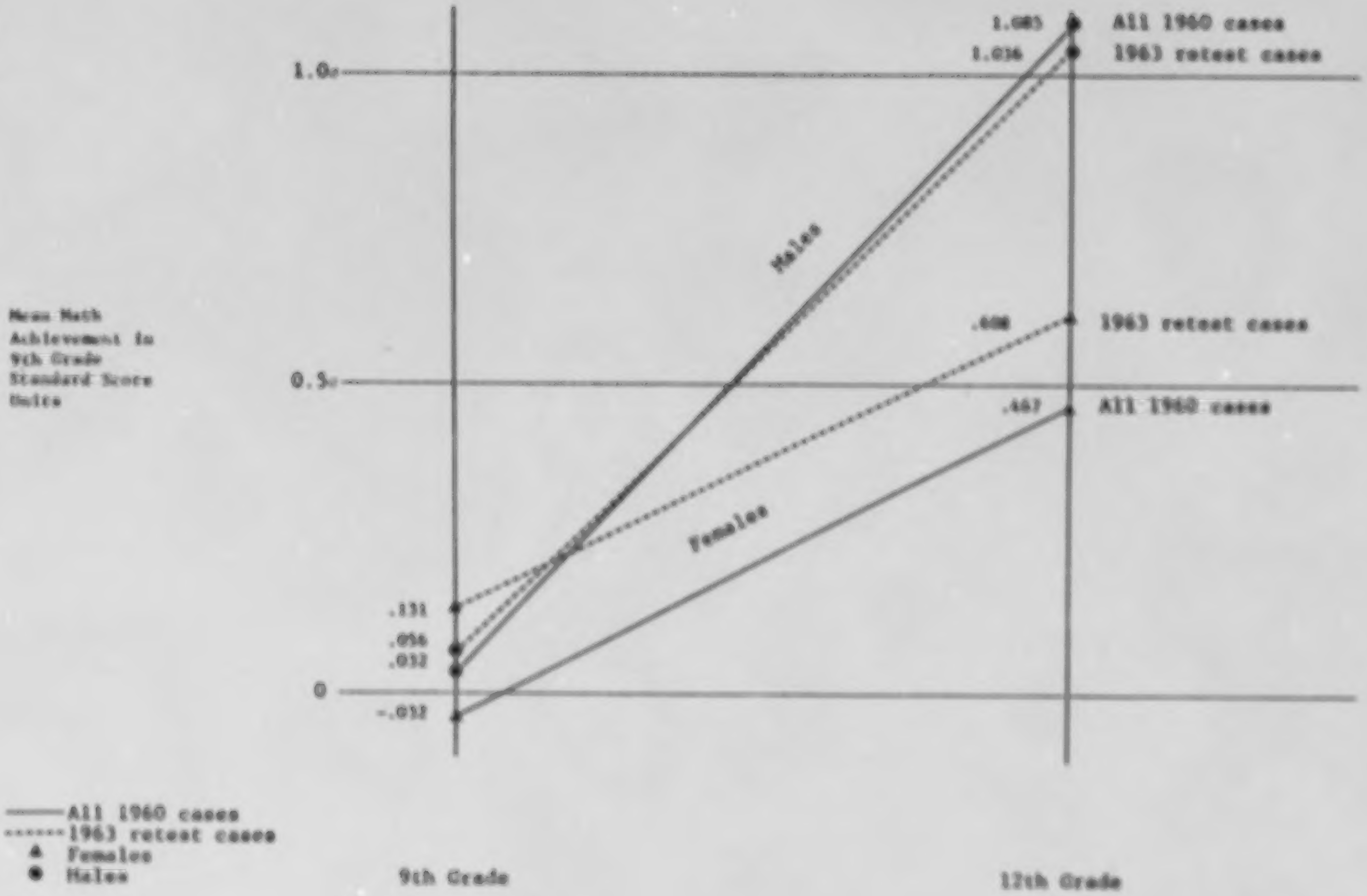

Figure 3. Comparison of the retest sample to the overall 1960 sample in terms of mean math achievement gains

such as Reading Comprehension or English, where there was some tendency for students with lower scores to "catch up.")

The positive correlation between 9th grade achievement and raw gain scores is undoubtedly related to the fact that students with higher 9th grade scores had a much higher rate of participation in elective math courses than their classmates ($r = .62$). Nonetheless, for students who took the same amount of math, their initial abilities were highly predictive of their final level of achievement (the correlation pooled within level of math taken and sex was .55; the partial correlation controlling for amount of math taken was .60). On the other hand, the amount of math taken also had a strong effect on 12th grade math achievement, independent of initial abilities (a partial correlation of .44).

The amount of math taken and 9th grade math achievement together have a multiple correlation of .84 with 12th grade math achievement, accounting for just over 70% of the variation. The multiple correlation begins to approach the reliability of the 12th grade math achievement measure (an upper bound), which was estimated by Shaycoft (1967, pp. 4-20) at .93 for males and .91 for females. Nevertheless, there are a number of variables that account for significant amounts of the remaining variation, as discussed below.

In order to assess the extent to which sex differences in 12th grade achievement could be explained by differences in math participation, a 2-way ANOVA with sex and amount of math taken as the independent factors was performed. Table 5 shows the results, which are further illustrated in Figure 4. The sex differences were literally nonexistent after controlling for amount of math taken, although there is a small interaction effect, with women scoring higher at moderate levels of math taken and males scoring higher at the extremes.

These results are, however, somewhat misleading, since they do not also include controls for initial abilities. Females who took advanced high school math were a more select group than males with the same level of participation. They tended to have higher levels of math ability to begin with. Table 6 shows another 2-way analysis of variance (sex x math taken) with 9th grade achievement controlled as a covariate. The results indicate that females with math participation and math ability equal to males had scores which averaged .1 standard deviation (based on 12th grade achievement scores) lower than male scores.

TABLE 5

Two-way Analysis of Variance of 12th Grade Math Achievement by Sex and Amount of Math Taken

```
* * * * * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * * * * *
            BR340 (12TH GRADE MATH ACHIEVEMENT)
         BY SEX
            MATHTKN (AMOUNT OF MATH TAKEN)
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *


                                      SUM OF                    MEAN             SIGNIF
SOURCE OF VARIATION                  SQUARES      DF          SQUARE        F      OF F

MAIN EFFECTS                       65895.750       7        9413.676  202.065    0.001
   SEX                                 1.064       1           1.064    0.023    0.999
   MATHTKN                         63821.520       6       10636.918  228.322    0.001

2-WAY INTERACTIONS                   692.000       6         115.333    2.476    0.022
   SEX        MATHTKN                692.023       6         115.337    2.476    0.022

EXPLAINED                          66587.750      13        5122.133  109.947    0.001

RESIDUAL                           53715.312    1153          46.587

TOTAL                             120303.062    1166         103.176

   1210 CASES WERE PROCESSED.
     43 CASES (  3.6 PCT) WERE MISSING.




* * *   M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S   * * *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

GRAND MEAN =    27.16                                                  ADJUSTED FOR
                                                      ADJUSTED FOR    INDEPENDENTS
                                          UNADJUSTED  INDEPENDENTS    + COVARIATES
VARIABLE + CATEGORY               N      DEV'N  ETA   DEV'N   BETA    DEV'N   BETA

SEX
     1                          546       1.42        -0.03
     2                          621      -1.25         0.03
                                                0.13          0.00

MATHTKN
     1                          178      -9.54        -9.54
     2                          222      -6.17        -6.18
     3                          228      -2.44        -2.44
     4                          229       0.79         0.79
     5                          163       9.20         9.21
     6                           87      12.12        12.13
     7                           60      14.81        14.82
                                                0.74          0.74

MULTIPLE R SQUARED                                            0.548
MULTIPLE R                                                    0.740
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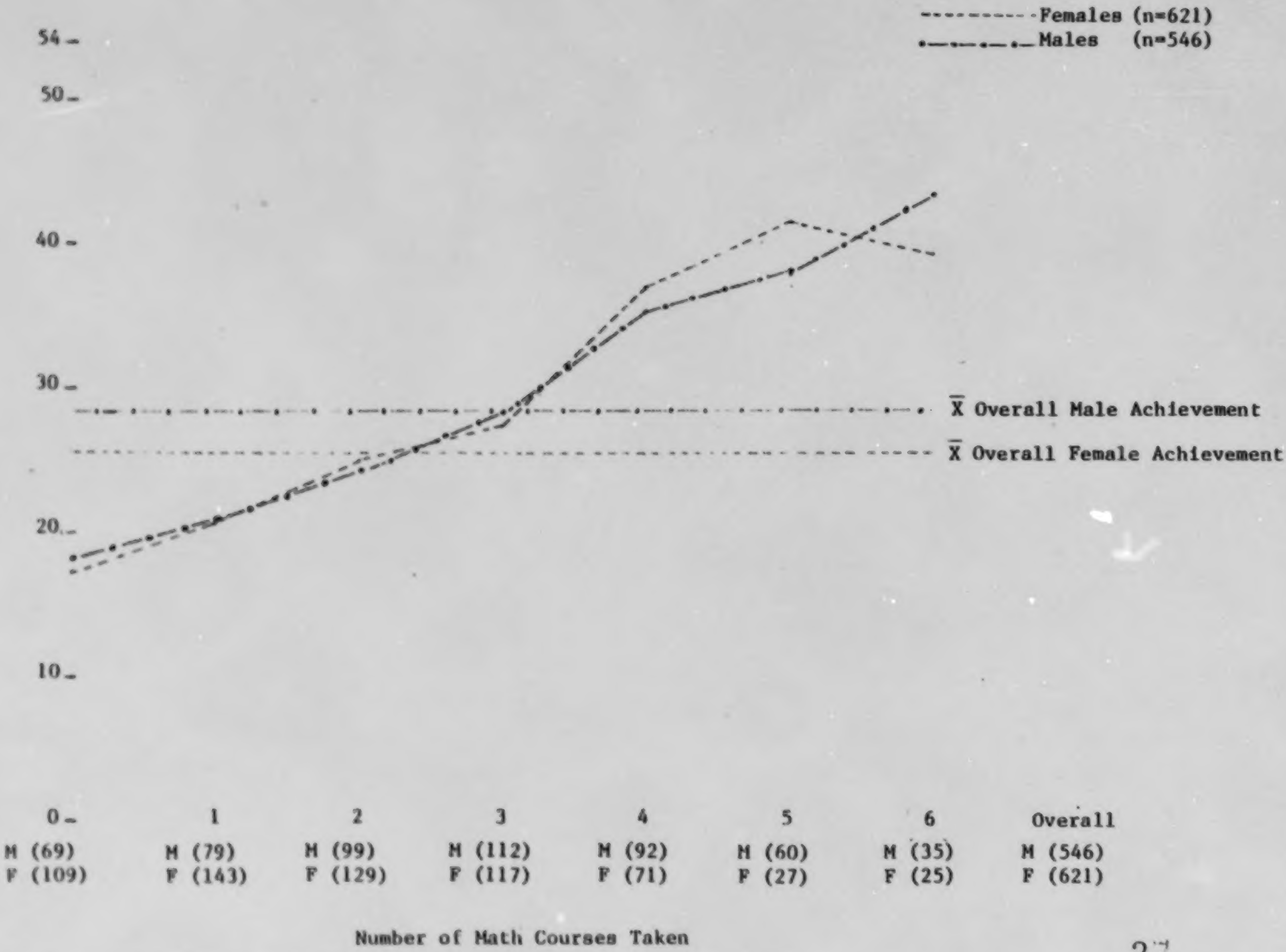

Figure 4. Mean 12th grade math achievement by number of courses taken

TABLE 6

Two-way Analysis of Covariance of 12th Grade Math Achievement by Sex and Amount of Math Taken Controlling for 9th Grade Math Achievement

```
* * * * * * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * * * * * *
            BR340 (12TH GRADE MATH ACHIEVEMENT)
         BY SEX
            MATHTKN (AMOUNT OF MATH TAKEN)
       WITH AMTHTOT(9TH GRADE MATH ABILITY)
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *


                                      SUM OF                   MEAN             SIGNIF
SOURCE OF VARIATION                  SQUARES     DF          SQUARE        F      OF F

MAIN EFFECTS                       83041.375      8       10380.172  350.018     0.001
   SEX                               271.084      1         271.084    9.141     0.003
   MATHTKN                         11484.086      6        1914.014   64.540     0.001
   AMTHTOT   (COVAR)               18977.605      1       18977.605  639.922     0.001

2-WAY INTERACTIONS                   139.687      6          23.281    0.785     0.999
   SEX       MATHTKN                 139.739      6          23.290    0.785     0.999

EXPLAINED                          83181.062     14        5941.504  200.347     0.001

RESIDUAL                           33096.250   1116          29.656

TOTAL                             116277.312   1130         102.900



COVARIATE          BETA

AMTHTOT           0.546

   1210 CASES WERE PROCESSED.
     79 CASES (   6.5 PCT) WERE MISSING.

* * *   M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S   * * *

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

GRAND MEAN =     27.15                                                     ADJUSTED FOR
                                                          ADJUSTED FOR     INDEPENDENTS
                                             UNADJUSTED   INDEPENDENTS     + COVARIATES
VARIABLE + CATEGORY                 N        DEV'N  ETA   DEV'N    BETA    DEV'N   BETA

SEX
     1                            533         1.44                          0.53
     2                            598        -1.28                         -0.47
                                                    0.13                            0.05

MATHTKN
     1                            174        -9.43                         -4.64
     2                            216        -6.21                         -3.66
     3                            222        -2.30                         -1.41
     4                            216         0.55                          0.17
     5                            159         9.29                          4.77
     6                             84        12.01                          7.23
     7                             60        14.82                          8.49
                                                    0.74                            0.41

MULTIPLE R SQUARED                                                                 0.714
MULTIPLE R                                                                         0.845
```

While this difference is significant, it is not large. Math taken and 9th grade achievement account for 71.1% of the variation in 12th grade achievement. Sex can account for 1.6% of the variation of 12th grade achievement when other factors are not controlled, but only .2% after controls are introduced. In this sense, roughly seven-eighths of the relationship between sex and 12th grade math achievement can be attributed to math taken and initial achievement.

Other Factors Predicting Gains in Math Achievement

Several exploratory regression analyses were performed on other background and 9th grade characteristic variables to identify additional predictors of math achievement. Three factors were identified as predictive of math achievement gains within level of math participation. These were:

- general academic aptitude, which includes both math and non-math aptitude and ability measures.
- interests in mathematics together with an expected occupation that requires math and a low interest in office work,
- low levels of participation in extracurricular activities in 9th grade.

The above three variables together with math participation and 9th grade math achievement form a general model for math achievement in high school. The essential ingredients of this model are:

- ability--including a foundation of knowledge of basic math concepts and also general academic skills;
- participation--exposure to math curriculum by enrolling in appropriate math courses and the lack of extensive extracurricular involvements that might detract from participation in the courses taken; and
- motivation--interest in math and math-related careers relative to interests in other careers.

Table 7 shows the results of the stepwise regression analysis that includes the variables in the general model.

While the general model applied to both males and females, a few significant sex differences were observed in searching for additional predictor variables. Males who had higher levels of Spatial Visualization and those who scored higher on Table Reading tended to show larger than

TABLE 7

Three-Step Regression of 12th Grade Math Achievement on Key Background and 9th Grade Characteristics

Step	Multiple R^2	Variables in the Equation			Other Variables		
		Variable	Beta	F	Variable	Partial R.	F
One	.719	Amount of Math Taken	.396	345.1	Sex	-.162	26.8
		9th Grade Math Achievement	.301	69.0	Math Level of Expected Occupation	.160	26.1
		9th Grade General Academic Aptitude	.263	58.2	Interest in Math	.143	20.8
					Interest in Office Work	-.123	15.3
					Degree of Participation in Extracurricular Activities	-.096	9.2
					Socioeconomic Status	.072	5.2*
Two	.733	Amount of Math Taken	.332	215.6	Degree of Participation in Activities	-.107	11.4
		9th Grade Math Achievement	.232	39.2	Socioeconomic Status	.072	5.2*
		9th Grade General Academic Aptitude	.326	87.0	Sex	-.056	3.2*
		Interest in Math	.092	20.8			
		Math Level of Expected Occupation	.046	5.1*			
		Interest in Office Work	-.067	12.0			
Three	.736	Amount of Math Taken	.341	226.5	Socioeconomic Status	.090	8.1
		9th Grade Math Achievement	.225	37.3	Sex	-.042	1.8*
		9th Grade General Academic Aptitude	.321	84.7			
		Math Level of Expected Occupation	.052	6.3			
		Interest in Office Work	-.058	8.9			
		Interest in Math	.098	23.4			
		Degree of Participation in Extracurricular Activities	-.057	11.4			

* Not significant at the .01 level (Based on an N of 1164).

expected achievement gains. This is consistent with the notion that males tend to use a spatial approach to math learning more than females. Scientific attitude (essentially a belief in lawfulness) and electricity and electronics knowledge were also significant predictors of math achievement for males.

For females, Socioeconomic Status and a number of related variables (low immediate concern with Earning a Living, high Law and Sports information) were significant predictors of math achievement. In addition, Self-Confidence was a much more significant predictor of math achievement for females than for males. This result is consistent with current widespread efforts to increase female math achievement through anxiety reduction (Tobias, 1976; Tobias and Donady, 1977).

While there are some significant sex differences in the residual factors that predict math achievement, it should be noted that none of these factors add even 1% to the percent of variation accounted for by the general model. Table 8 gives some further perspective on the relative contribution of various factors to sex differences in math achievement. Differences in the amount of math taken are by far the most significant component of math achievement differences. Interests in math and math-related careers relative to interest in office work also play a very significant role. Any intervention that does not affect one or both of these factors is unlikely to have a very large effect in reducing sex differences in achievement levels.

Predictors of Math Participation

As with 12th grade math achievement, the largest correlate of the amount of math taken was 9th grade math achievement ($r = .62$). For individuals with equal initial achievement, their expected educational attainment was the most significant predictor of level of math participation (with a partial correlation of .39). The variable Educational Expectations accounts for an additional 9% beyond variation accounted for by 9th grade math achievement of the variance of 12th grade math achievement. However, since sex differences in both math achievement and educational expectations are relatively small in the 9th grade, neither of these factors accounts for very much of the sex differences in math participation.

Several other variables that predict math participation after controlling 9th grade achievement and educational expectations explain the

TABLE 8

Sex Differences in Math Achievement Predicted by Each Variable in the General Regression Equation

Predictor Variable	Mean Sex Difference in Predictor Variable	Regression Coefficient	Predicted Sex Difference	% of Actual Sex Difference
9th Grade Math Achievement	.376	.236	.089	3.5%
Amount of Math Taken	.602	2.041	1.229	47.8%
General 9th Grade Academic Aptitude	-23.303	.032	-.746	-29.0%
Math Level of Expected Occupation	1.574	.371	.584	22.7%
Interest in Math	4.585	.089	.408	15.9%
Interest in Office Work	-10.217	-.058	.593	23.1%
Degree of Extracurricular Activity	-2.144	-.038	.081	3.2%
Total Sex Predicted Difference			2.238	87.2%
Actual Sex Difference			2.569	
Amount Explained by Other Factors			.331	12.8%

Multiple Correlation = .86

Variance Accounted for = 74%

significant sex differences in math participation. These are measures of interest in math-related careers relative to interest in office work and interest in math itself.

The final regression equation for predicting math participation is shown in Table 9. It includes one additional variable, intention to take a college preparatory program, which is closely related to educational expectations. Table 9 also shows that sex differences in the interest variables account for most of the sex differences in participation.

Table 10 lists the variables for each sex that have significant correlations with math participation after controlling for the variables in the general regression equation shown in Table 9. For males, Table Reading, Spatial Visualization, and Information about Foreign Countries were significant predictors of math participation "gains." The first two of these variables have demonstrated relationships to mathematics ability (Fennema & Sherman, 1977b); the latter variable is most likely an indicator of general knowledge and ability levels. In addition, males who had discussed their plans with counselors more frequently in the 9th grade tended to end up with lower participation rates. This may be because they were planning a specific career that did not require math, since the Prestige of the Planned Career was negatively related to math participation gains.

For females, much of the remaining variation in math participation was related to fathers. The Prestige and Math Level of the Father's Career were significantly related to the amount of math taken by the daughter, as was the number of times in the 9th grade she discussed post-high school plans with her father and not with a school counselor. Parental expectations regarding college was also a significant predictor of math participation for women.

Relationships Between (1) Characteristics of Schools and School Environments and (2) Math Participation and Achievement

In order to analyze the relationship of school characteristics to student participation and achievement in math, the student data were aggregated at the school level. In all, there were 54 schools for which math achievement data were available and 44 schools for which math participation data were available. After discarding schools in which fewer than 10 students were retested, there were 44 schools with math achievement data and 40 schools with math participation data.

TABLE 9

Sex Differences in Math Participation Predicted by Each Variable in the General Regression Equation

Predictor Variable	Mean Sex Difference in Predictor Variable	Regression Coefficient	Predicted Sex Difference	% of Actual Sex Difference
9th Grade Math Achievement	.376	.065	.024	4.0%
Expected Level of Education	.231	.264	.061	10.1%
College Preparatory Curriculum	.048	.475	.023	3.8%
Interest in Math	4.584	.022	.101	16.8%
Interest in Math-Related Careers	9.301	.015	.140	23.3%
Interest in Office Work	-10.217	-.015	.153	25.4%
Total Predicted Sex Difference			.502	83.4%
Actual Sex Difference			.602	
Difference Resulting from Other Factors			.100	16.6%

Multiple Correlation = .73

Variance Accounted for = 53%

TABLE 10

Partial Correlations of Background and 9th Grade Characteristic Variables with the Amount of Math Taken by Sex

Name of Variable	Partial Correlation[1] Females	Males
Variables Significant for Females		
Father's Characteristic		
Prestige of Father's Occupation	.14***	-.03
Math Level of Father's Occupation	.11*	-.03
Change in Head of Household	-.12*	.03
Discuss Plans with Father	.11*	-.08
Parents' Educational Expectation	.12*	-.08
Academic Program		
Academic Level of High School Coursework	.14***	.02
Number of Science Course Taken	.13***	-.02
Interests and Plans		
Expected Number of Children	.11*	-.03
Cultural Activities	-.11**	-.05
Computational Interests	-.11*	-.01
Discussed Plans with Counselor	-.12**	-.13**
Variables Significant for Males		
Knowledge and Abilities		
Visualization in 3-Dimensions	.06	.13**
Table Reading	.03	.14**
Information on Foreign Countries	.00	.15***
Career Interests and Plans		
Biological Science, Medicine Interest	-.11*	-.14**
Prestige of Expected Occupation	.02	-.13*
Guidance Received in High School	-.09	-.14**
Discussed Plans with Counselor	-.12**	-.13**

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[1] Partial correlations after controlling for 9th grade abilities, interests and plans.

* significant at the .01 level

** significant at the .005 level

*** significant at the .001 level

The "expected" math participation and 12th grade math achievement levels of each student were computed based on the background and 9th grade characteristics variables shown in Table 11. The difference between the actual and predicted levels, the "unexpected" gains, were computed for each student and then averaged over all students in each school. In addition, the "unexpected" mean gains for females in each school were computed. The mean unexpected gains (or losses) were then correlated with variables from the General School Characteristics Questionnaire. The most significant correlations are shown in Tables 12 and 13.

A number of key school characteristics were found to be significantly correlated with 12th grade achievement and participation levels, but not with the unexpected gains in these levels. For 12th grade achievement this included financial characteristics (per-pupil expenditure, percent support from local sources), teacher characteristics (number, training, and experience of teachers), and characteristics of the student body (percent college bound). These variables were all correlated with the expected participation and achievement gains. For example, teachers with higher levels of training and experience were more prevalent in schools whose entering students were more able.

In examining achievement gains, two variables were found to predict "unexpected" gains as well as predicting overall achievement. The observed relationship between high absenteeism and low achievement was not surprising, although the strength of the relationship may be. The relationship between the tax rate and achievement gains was less obvious, particularly in light of the much lower correlations for per-pupil expenditures. One explanation that warrants further investigation is that the tax rate is an indicator of the value a local community places on education, and that this value is also related to increased achievement.

One variable, the availability of accelerated science curriculum, was a significant predictor of "unexpected" achievement gains for girls but not for boys. This finding was investigated further by correlating the availability of an accelerated science curriculum with the most significant predictors of math achievement. The results showed that there was a much greater reduction in female interest in office work in schools with an accelerated science curriculum (r = .12, significant at the .01 level). The male interest levels were relatively unchanged (r = -.01). The

TABLE 11

Regression Equations for Predicting Math Participation and Achievement from Background and 9th Grade Characterisitic Variables

Variable	Regression Coefficient	Beta
Math Achievement		
9th Grade Math Achievement	.2957	.183
Expected Level of Education	.2952	.042
General 9th Grade Academic Aptitude	.0352	.354
Interest in Math	.1294	.143
Interest in Office Work	-.0924	-.092
Grade in Math (9th Grade)	.7924	.103
Math Level of Expected Career	.6485	.090
Socioeconomic Status	-.0865	.084
Participation in Extracurricular Activities	.0342	-.052
Constant	-13.8939	
Math Participation		
9th Grade Math Achievement	.0716	.411
Expected Level of Education	.3244	.274
Interest in Math-Related Careers	.0117	.063
Interest in Office Work	-.0224	-.134
Interest in Math	.0217	.144
Constant	-.212	

TABLE 12

Correlation of 12th Grade Math Achievement Gains with General School Characteristics

	Partial Correlation with 12th Grade Math Achievement	Partial Correlation with 12th Grade Math Achievement for Females only	First Order Correlation with 12th Grade Math Achievement
I. Variables correlated with "expected" 12th grade math achievement gains but not with "unexpected" gains.			
Honors Courses	0.03	0.09	0.48***
Number of Full-time Teachers	-0.03	0.13	0.30
Staff Experience/Training	0.02	0.10	0.40**
% Students Enrolled in College Prep Courses	0.06	-0.01	0.45**
% Males and Females Going on to College	0.08	0.12	0.51***
Expenditure per pupil	0.17	0.14	0.35*
II. Variables correlated with "unexpected" 12th grade math achievement gains.			
% of Daily Absenteeism	-0.29	-0.36*	-0.39**
Current School Tax per $1000	0.41**	0.26	0.44**
III. Variables correlated with "unexpected" 12th grade math achievement gains for females			
Accelerated Curriculum in Science	0.15	0.32*	0.22

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*significant at the .01 level
**significant at the .005 level
***significant at the .001 level

TABLE 13

Correlation of Math Participation Level with General School Characteristics

	Partial Correlation with Math Participation Level	Partial Correlation with Math Participation Level for Females only	First Order Correlations with Math Participation Level
I. Variables correlated with "expected" math participation levels, but not with "unexpected" levels.			
Honors Courses	0.21	0.21	0.55***
Accelerated Math Curriculum	0.18	0.18	0.35*
Number of Full-time Teachers	0.03	0.04	0.30
Staff Experience/Training	0.04	0.07	0.35*
% Students Enrolled in College Prep Courses	0.18	-0.02	0.53***
% Males and Females Going on to College	-0.09	-0.23	0.48***
Per Pupil Expenditure	-0.10	-0.05	0.40**
% School Support from Local Sources	-0.00	-0.27	0.42**
II. Variables correlated with "unexpected" math participation levels.			
Count of School Facilities Available	-0.27	-0.22	0.03
III. Variables correlated with "unexpected" math participation levels for females.			
% Parents in P.T.A.	0.14	0.27	-0.11
Frequency of Standardized Testing	0.22	0.36*	0.19

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*significant at the .01 level
**significant at the .005 level
***significant at the .001 level

availability of an accelerated science curriculum seems to have encouraged females to widen their career interests.

Most of the same financial, teacher, and student body variables that predicted expected overall achievement gains were found also to predict math participation. The availability of an accelerated curriculum in math and science showed marginally significant relationship to "unexpected" levels of participation as well as to the overall level. The variety of "facilities" available to students was related to lower than expected math participation (although this variable was not at all related to overall participation levels). This was surprising and should be investigated further.

Two variables were found to predict higher than expected participation levels for females but not for males. The percent of parents in the PTA may indicate the kind of parental interest and support that encourages females to elect to pursue mathematics. Why this is more important for females than for males warrants further investigation. The frequency of standard testing was also found to be a much stronger predictor of math participation for females than for males. This may reflect the effects of a greater thoroughness in counseling and testing in some schools, or it may reflect the effect of increased confidence in females resulting from a greater awareness of their own abilities.

Relationships Between (1) High School Experiences and 12th Grade Characteristics and (2) Higher than Expected Levels of Math Participation and Achievement

Table 14 lists the 12th grade experiences and characteristics that were correlated with 12th grade math participation after controlling for 9th grade characteristics. Because these measures were collected at the same time that 12th grade achievement was assessed, it is inappropriate to make causal inferences regarding these relationships. It is quite likely that the effects go both ways (e.g., increased math participation may influence interest in math-related careers which, in turn, influences continued participation).

Expectations regarding college were highly related to increased levels of math participation for both males and females, as shown in Table 15. Several interest variables were also closely related to math participation for both males and females, including interest in math-related careers and

TABLE 14

Correlations By Sex of 12th Grade Characteristics and Experiences with Math Participation Relative to Predictions Based on 9th Grade Characteristics

Variable	Partial Correlation* With 12th Grade Math Participation		First Order Correlation* With 12th Grade Math Participation	
	Male	Female	Male	Female
Science Courses Taken (SCITKN)	.31	.27	.51	.46
Business/Vocational Courses (BSIB111)	-.19	-.33	-.33	-.34
Grades in All Courses (BSIB115)	.12	.05**	.08	.29
12th Grade Math Achievement (BR340)	.24	.24	.72	.74
Math Level of Expected College Major (BMTHMAJ)	.30	.22	.51	.47
Increased Interest in Math (CMTHINT)	.20	.19	.06	.12
12th Grade Math Interest (BMTHINT)	.22	.16	.46	.40
Expected Level of Education (BSIB064)	.27	.24	.60	.59
Expect to go to College (BSIB059)	.30	.28	.60	.59
Discussed College Plans with Teachers/ Counselors (COLLNCL)	.24	.18	.46	.45
Discussed Career Plans with Teachers/ Counselors (CARCNCL)	NS	-.13	-.13**	-.12
12th Grade Interest in Math-Related Careers (BP701)	.14	.11	.40	.41
Increased Interest in Math-Related Careers (CP701)	.14	.12	.06**	.09
12th Grade Interest in Office Work (BP713)	NS	-.20	-.06**	-.40
Decreased Interest in Office Work (CP713)	NS	-.18	NS	-.17
12th Grade Interest in Skilled Trade (BP715)	.14	NS	.29	NS
Level of College Expected (BSIB060)	.26	.25	.56	.56
Expect to Attend College Full-time (BSIB062)	.25	.25	.52	.52
Expect to Attend Business or Commercial School (BSIB058)	-.11	-.17	-.26	-.32
Math Level of Expected Occupation (BOCCMTH)	.22	-.14	.41	.32
Prestige of Expected Occupation (BOCCPRS)	.18	.19	.40	.39
Grade When Present Career Choice Made (BSIB242)	.11	N	.10	-.05**

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*All correlations at .01 level of significance except as noted above

**Significance level between .05 and .01

NS = Significance level greater than .05

TABLE 15

12th Grade Math Participation* by Type of College Expected to Attend, Planned Start of College, and Type of High School Program

	Males			Females		
	Mean	(N)	Eta^2	Mean	(N)	Eta^2
Type of College						
University	0.74	(220)		0.22	(211)	
Engineering College	0.66	(119)		-0.61	(8)	
Some Other College	-0.26	(106)		-0.03	(186)	
Liberal Arts College	0.39	(174)		0.38	(190)	
Teachers' College	0.16	(93)		0.33	(137)	
Agricultural College	-0.56	(32)		-0.64	(5)	
Music/Fine Arts	-0.23	(11)		0.06	(22)	
Do Not Expect to Attend	-0.97	(250)		-0.27	(307)	
No Plans	-0.62	(53)		-0.27	(51)	
			.310			.069
Planned Start						
Right After High School	0.56	(597)		0.29	(600)	
After Military Service	-0.06	(45)		-0.93	(4)	
Work for A Few Years	-0.49	(44)		0.05	(39)	
Maybe in Future	-0.67	(85)		-0.09	(92)	
No College Plans	-0.93	(273)		-0.30	(547)	
			.312			.076
Type of Program						
College Preparatory	0.37	(552)		0.49	(571)	
General	-0.33	(328)		-0.18	(280)	
Commercial/Business	-0.61	(71)		-0.51	(436)	
Other Program	0.08	(26)		-0.05	(22)	
Vocational	-0.46	(94)		-0.19	(25)	
Agricultural	-0.52	(22)		-0.87	(3)	
			.452			.163

*In standard score units after controlling for 9th grade characteristics.

in math itself. The degree of change in these interests over the high school years was as significant as the overall level of interest in predicting math participation beyond expectations. For females, interest in office work and pursuit of business or vocational courses in high school were characteristic of those who ended up taking less math than expected. A high interest in skilled trades was characteristic of males who took less math than expected.

Career plans were also closely related to math participation. The math level of their expected careers (generally related to whether college was required) was related to the amount of math taken beyond predicted amounts, as was the prestige level of the expected career. For those going to college, the math level of their expected major was also a strong correlate of the amount of math the participants took during high school (see Table 16). There was also a small but significant sex difference in the relationship between the timing of career decisions and math participation. Males who had developed career plans at an earlier age tended toward lower math participation rates, while this relationship was not significant for females. In general, however, males who changed their career plans tended to change to occupations requiring lower levels of math, while women who changed moved toward occupations requiring more math (although still considerably less, on the average, than their male counterparts). Table 17 shows these results.

Since math participation was a strong determinant of 12th grade math achievement levels, the 12th grade variables that were correlated with participation were also correlated with achievement. A few 12th grade characteristics were correlated with achievement, even after controlling for math participation as well as 9th grade characteristics. These are shown in Table 18. Most of these variables are related to the relevance of math to the students' career plans (math level of expected career, interest in math-related careers, math level of expected college major) or to interest in math itself. Both the absolute level of these variables and the change from grades 9 to 12 were significantly related to achievement beyond expectations.

Tables 19 and 20 show relationships between high school math achievement and college plans after controlling for participation and for 9th grade characteristics. There are significant relationships for both males and

TABLE 16

12th Grade Math Participation* by Expected College Major

Math Level	Expected Major	Males Mean (N)	Females Mean (N)
6	Mathematics	0.93 (45)	0.78 (35)
5	Engineering	0.78 (171)	-0.80 (7)
5	Physical Science	0.89 (40)	1.28 (15)
4	Biological Science	0.64 (26)	0.14 (29)
4	Pre-Medical	0.83 (40)	0.30 (23)
4	Pre-Dental	0.58 (20)	0.11 (10)
3	Political Science or Economics	0.37 (21)	-0.38 (10)
3	Sociology or Psychology	-0.13 (20)	0.39 (38)
3	Education	0.01 (47)	-0.23 (178)
3	Nursing	—	0.36 (109)
3	Pre-Law	0.11 (44)	-0.61 (7)
3	Business Administration	0.04 (142)	-0.40 (127)
2	Pre-Theology	0.25 (7)	-0.98 (1)
2	Foreign Language	-0.10 (4)	0.66 (26)
2	Other Liberal Arts	0.02 (27)	0.18 (41)
2	Fine Arts	0.08 (31)	0.12 (51)
2	Agriculture	-0.63 (17)	2.44 (1)
2	Home Economics	—	0.05 (28)
2	Journalism	-0.42 (4)	0.52 (15)
2	Other Program (NFC)	-0.08 (92)	0.06 (86)
1	No Plans	-0.41 (66)	-0.27 (66)
1	Do Not Expect to Attend	-1.03 (228)	-0.29 (635)
	Eta	.308	.117

*In standard score units after controlling for 9th grade characteristics.

TABLE 17

Differences in the Math Level of 9th and 12th Grade Career Plans for Males and Females

	Math Level of Expected Career	
Grade	Males	Females
9th Grade	3.76 ± .04	2.22 ± .03
12th Grade	3.19 ± .04	2.47 ± .02
Change	-.67 ± .01	.25 ± .01

TABLE 18

Correlations by Sex of 12th Grade Characteristics and Experience with Math Achievement Relative to Predictions Based on 9th Grade Characteristics

Variable	Partial Correlation* with 12th Grade Math Achievement		First Order Correlation* with 12th Grade Math Achievement	
	Male	Female	Male	Female
Math Level of Expected College Major	.19	.13	.48	.47
Increased Interest in Math	.16	.18	NS	.11
Math Level of Expected Occupation	.12	.11	.38	.34
12th Grade Math Interest	.15	.16	.41	.45
Prestige of Expected Occupation	.11	.11	.36	.35
Grades in Math Courses	.14	NS	.43	.42
Increased Interest in Math-Related Careers	.12	.12	NS	.11
12th Grade Interest in Math-Related Careers	.11	.09**	.37	.44
Grade When Present Career Choice Made	.17	NS	NS	-.14

*Correlations at less than .01 level of significance

**Significance level between .05 and .01

NS = Significance level greater than .05

TABLE 19

12th Grade Math Achievement* By Type of College Expected to Attend and Planned Start of College

	Males			Females		
	Mean	(N)	Eta^2	Mean	(N)	Eta^2
Type of College						
University	0.31	(67)		0.22	(57)	
Engineering College	0.26	(40)		-0.39	(2)	
Some Other College	0.13	(54)		0.03	(53)	
Liberal Arts College	-0.04	(65)		0.37	(61)	
Teachers College	-0.30	(29)		-0.14	(41)	
Agricultural College	-0.43	(12)		0.47	(2)	
Music/Fine Arts College	-0.58	(3)		0.65	(8)	
Do Not Expect to Attend	-0.21	(80)		-0.15	(161)	
No Plans	-0.22	(15)		-0.68	(10)	
			.053			.052
Planned Start of College						
Right After High School	0.08	(96)		0.16	(196)	
After Military Service	-0.22	(231)		--	--	
Work for A Few Years	-0.26	(21)		-0.40	(16)	
Maybe in Future	0.10	(12)		-0.25	(30)	
No College Plans	-0.20	(32)		-0.10	(170)	
			.017			.025

*In standard score units after controlling for Math Participation and 9th grade characteristics.

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TABLE 20

12th Grade Math Achievement* By Expected College Major

Expected Program	Males		Females	
	Mean	(N)	Mean	(N)
Mathematics	0.67	(75)	0.58	(12)
Engineering	0.29	(61)	0.00	(1)
Physical Science	0.28	(9)	0.88	(5)
Biological Science	-0.09	(7)	0.00	(9)
Pre-law	0.21	(21)	0.47	(3)
Business Administration	0.05	(56)	-0.13	(45)
Pre-medical	0.08	(11)	0.03	(7)
Pre-dental	-0.28	(9)	-0.06	(5)
Political Science or Economics	-0.06	(8)	0.41	(2)
Sociology or Psychology	-0.07	(6)	0.64	(6)
Education	-0.50	(17)	0.07	(55)
Other liberal arts	-0.28	(11)	-0.15	(8)
Fine Arts	-0.51	(12)	0.43	(16)
Agriculture	-0.16	(8)	-	
Nursing	-		-0.03	(41)
Home Economics	-		0.23	(7)
Other Program (NEC)	-0.08	(39)	-0.15	(26)
No Plans	0.17	(24)	-0.16	(26)
Do not Expect to Attend	-0.25	(75)	-0.01	(135)
Eta Squared	0.073		0.043	

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*in standard score units after controlling for Math Participation and 9th grade characteristics females in the type of college they expect to attend and in how soon they expect to start, and also in the major they plan to pursue.

The relevance of math for college and career plans is closely related to math participation and to achievement within participation levels. Whether the plans affect math participation and achievement or the plans are affected by them or both, it is clear that the relevance of math to students' plans is central to math learning in high school.

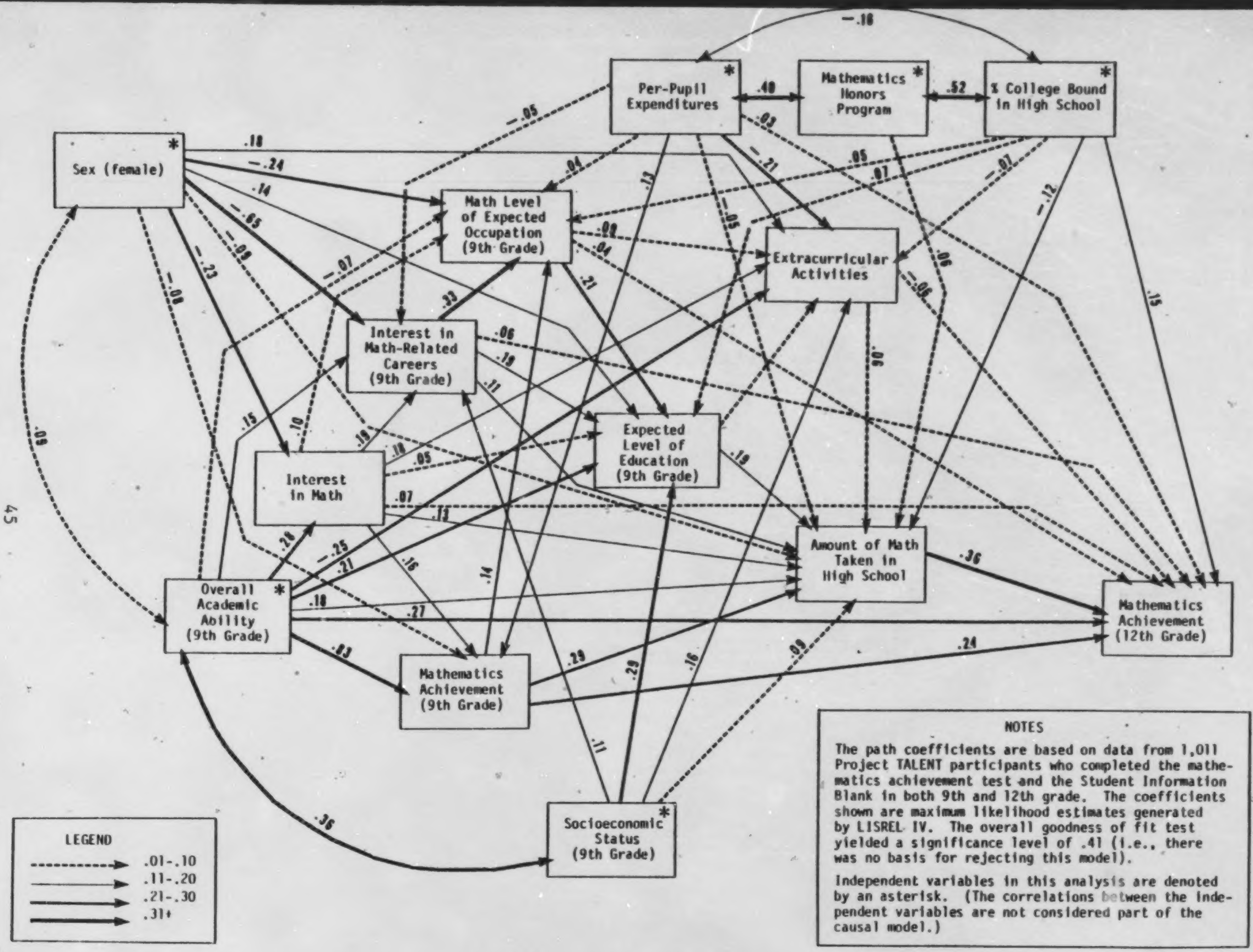
Summary Model of Relationship of Sex to High School Mathematics Achievement

The final step in the data analyses carried out in this study was to examine the process by which sex and other independent variables (e.g., SES, general academic aptitude, and school characteristics) relate to high school math participation and achievement. Structural models incorporating those independent and moderator variables found to have the strongest relationships to math participation and achievement were developed and tested using the LISREL IV programs (see Joreskog, 1971, for a detailed discussion of this technique). Figure 5 shows the model that best summarized the data.

The path coefficients are maximum likelihood estimates. That is, the values shown lead to predicted intercorrelations between the variables that maximize the likelihood of obtaining the observed sample correlation matrix. In this case the probability of obtaining a sample correlation matrix at least as discrepant from the predicted matrix as the one we actually observed was .41. Thus the observed data did not in any way reject this model. Of course this in no way proves our causal model, but it does indicate a high degree of plausibility for the model shown.

The path coefficients shown reflect the simultaneous effects of different factors leading to the same outcome. The primary variable of interest, mathematics achievement, was measured at two points in time with the two measures being strongly related. Other paths leading to 12th grade math achievement predict achievement independent of 9th grade level (or predict differences for individuals at the same 9th grade level).

As can be seen, the primary "effects" of sex on high school math achievement are through math participation. Indeed, there are no direct relationships between sex and 12th grade math achievement. While both overall academic ability and 9th grade math achievement also had strong


Per-Pupil Expenditures *
Mathematics Honors Program *
% College Bound in High School *
Sex (female) *
Math Level of Expected Occupation (9th Grade)
Extracurricular Activities
Interest in Math-Related Careers (9th Grade)
Expected Level of Education (9th Grade)
Interest in Math
Amount of Math Taken in High School
Overall Academic Ability (9th Grade) *
Mathematics Achievement (12th Grade)
Mathematics Achievement (9th Grade)
Socioeconomic Status (9th Grade) *
-.18
.40
.52
-.05
.18
-.24
.14
-.65
-.08
-.23
-.08
.04
-.03
-.21
.13
-.05
.05
.07
-.07
-.12
.15
.08
.04
.06
.21
.33
-.07
.06
.19
.11
.06
.15
.10
.19
.10
.05
.07
.13
.19
.09
.28
-.25
.21
.16
.18
.27
.14
.83
.36
.29
.29
.16
.09
.24
.11
.36
LEGEND
.01-.10
.11-.20
.21-.30
.31+

NOTES

The path coefficients are based on data from 1,011 Project TALENT participants who completed the mathematics achievement test and the Student Information Blank in both 9th and 12th grade. The coefficients shown are maximum likelihood estimates generated by LISREL IV. The overall goodness of fit test yielded a significance level of .41 (i.e., there was no basis for rejecting this model).

Independent variables in this analysis are denoted by an asterisk. (The correlations between the independent variables are not considered part of the causal model.)

Figure 5. Summary path model of the relationship of sex to high school mathematics achievement

direct influences on 12th grade math achievement ($b = .27$ and $b = .24$ respectively), neither variable had an especially strong relationship with sex.

The relationship between sex and math participation is somewhat complex, with the sex "effect" being primarily attributable to women's lesser interest in math ($b = -.23$), interest in math-related careers ($b = -.65$), and to the lower math level of women's planned careers ($b = -.24$). All but the last of these variables had direct "effects" on math participation. In addition, both interest in math-related careers and math level of expected occupation also "affected" math participation indirectly, through their positive "effect" on educational expectations. A modest positive direct effect of sex on educational expectations ($b = .14$) was also observed; this is probably due to the effects of sex differences in career interests and plans being controlled. The combined indirect "effect" of sex through these variables, even with the positive sex "effect" on educational expectations (after all other variables were controlled), was $b = -.13$, which exceeds the direct "effect" of sex on math participation ($b = -.09$).

While both overall academic abilities and 9th grade math achievement strongly influenced participation in high school math courses, their modest relationships with sex suggest that these factors operate independently and do not account for much of the sex difference in math participation. (The combined sex "effects" through academic aptitude and 9th grade math achievement were $b = .04$ and $b = -.02$, respectively.) Similarly, women's greater participation in extracurricular activities had only a modest influence on their participation in high school math courses (combined $b = .01$).

The observed sex differences in math achievement by the end of high school, then, can be explained by differences in career interests and plans which are evident at the beginning of high school and which strongly influence the number of high school math courses taken.

While neither socioeconomic status (SES) nor school characteristics explained any of the sex difference in high school math participation and achievement, it is worth noting that both appeared to be salient determinants of math participation and achievement in general. SES appeared to influence math participation both directly ($b = .09$) and through the higher educational expectations associated with higher SES backgrounds (combined $b = .06$).

Three school characteristics were also found to influence math participation and/or achievement net of effects attributable to other variables. Per-pupil expenditures "affected" math participation directly (b = -.05) and indirectly, through 9th grade math achievement (combined b = .04). The availability of a math honors program had a modest direct effect on math participation (b = .06). Finally, the proportion of the student body planning to attend college had strong direct effects on both participation (b = -.12) and 12th grade achievement (b = .15), as well as a very modest indirect effect on math participation through decreased participation in extracurricular activities (combined b = -.004). It would appear from the latter findings that among students of equal abilities, those whose peers are more academically able (as inferred from the proportion of students planning on attending college) may be less likely to participate in higher level math courses in high school, perhaps due to increased competition from their peers. However, those who do participate will be likely to have higher levels of achievement in this more challenging environment.

Summary and Conclusions

The goal of this study was to identify the origins of observed sex differences in high school mathematics achievement. At the beginning of high school, men and women did not differ significantly in their levels of math achievement, but by 12th grade the boys had gained over twice as much as the girls. Twelfth grade math achievement in general was found to be a function of ninth grade abilities (both math achievement and general academic aptitude). This sex difference in twelfth grade achievement was found to be related to participation in elective math courses (and a somewhat lower degree of participation in extracurricular activities) and interest in math and math-related careers relative to interest in office office work. Of these factors, sex differences in participation accounted for almost all of the sex differences in achievement.

Both males and females who achieved above expectation showed increases in interest in math and on math-related careers from the 9th to the 12th grade. In the 12th grade, they were also more likely to be planning college majors and careers requiring higher than average levels of mathematics. Beyond these factors, males who achieved beyond the level predicted by the above variables tended to "specialize" in math and science. They had high 9th grade scores on the physical science and electricity and electronics information scales and on the scientific attitude scale, and they had low levels of participation in sports, hobbies, and other extracurricular activities. Females who achieved beyond the predicted level tended to show high levels of knowledge in a wide range of areas (e.g., law, sports, home economics, biological science). They tended to come from higher socioeconomic status families, and this advantage may have led to their higher knowledge levels. They were also more frequently in leadership roles and had above average self-confidence scores.

Participation in mathematics in high school was found to be a function of (1) ninth grade abilities in math, (2) educational expectations, and (3) interest in math and math-related careers relative to interest in office work. Sex differences in math participation were primarily related to sex differences in interests.

The above three general factors accounted for 53% of the variation in math participation. The factors that accounted for additional variation (albeit only small amounts) differed for males and females. Self-confidence was significantly related to math participation for females, as were father's characteristics, the academic level of their high school course work, and the number of science courses that they took. However, these factors show no relationship to math participation for males when abilities, educational expectations, and interests are controlled. Two specific abilities, spatial visualization and table reading, accounted for additional variation in math participation for males but not for females.

Both males and females who discussed their plans with counselors more frequently than other students were likely to take less math than might otherwise be expected. This is probably because college-bound students who are more likely to take math felt less need to talk to counselors. Nonetheless, the role of high school counselors in encouraging (or discouraging) math participation deserves further investigation, particularly in light of the importance of career-related interests in math participation and achievement.

Much of the effect of school programs on math participation and achievement is masked by correlations between student and school characteristics. However, two school factors were found that significantly reduced sex differences in math participation and achievement. These are the frequency of standardized testing and the availability of an accelerated curriculum in science.

Frequency of Standardized Testing in math was found to be significantly related to math participation (controlling for 9th grade student characteristics), particularly for females. It is possible that schools that use standardized tests more tend to be more thorough in assessing students' abilities and encouraging students to pursue courses related to their abilities; this may serve to counteract other, more negative influences in math participation for women. The use of standardized tests may also relate to the increased self-confidence found for women with higher math participation levels, in that feedback from such tests may serve to increase women's self-confidence.

The availability of an accelerated science curriculum (but not the availability of an accelerated math curriculum) was significantly related to math achievement for females after controlling for 9th grade characteristics. Since female interest in office work was found to decrease significantly between grades 9 and 12 in schools with accelerated science curricula, it seems likely that such accelerated curricula increased the perceived utility of mathematics by broadening career interests, particularly for females.

The findings from this study contain many implications for educational policies and practices aimed at reducing sex differences in math participation and math achievement. Recommendations regarding the objectives, the timing, and the target populations of particular interventions are discussed below, followed by a brief review of implications for further research.

Objectives. Several objectives for educational policies and practices aimed at reducing sex differences in math participation and thus in achievement can be derived from these results. In particular, policies and practices should seek to:

1. increase young women's interest in math and math-related careers and in other alternatives to office work; and
2. increase their educational expectations, so that they are more appropriate to their abilities.

In addition, educational interventions that increase women's self-confidence will also be likely to result in increased math participation, although self-confidence accounts for a smaller proportion of the variance than do the other factors. (It is possible that confidence regarding mathematics per se would be a more salient determinant of math participation, but it was not possible to investigate that variable in this study.)

Career education and guidance would appear to be a critical mechanism for meeting these objectives. Not only can career education help expand young women's knowledge of careers and the range of career options they consider, it can also work to eliminate sex stereotyping in career perceptions and attitudes for both young men and young wmen. Counseling and guidance personnel also have a potential role in helping to accomplish these objectives. In particular, they could help young women at all levels to consider the longer-term career implications of decisions regarding high school courses, as well as the implications for meeting high school graduation and/or college entry requirements. However, more should be learned about the relationship between student-counselor interactions and math participation. Finally, specific programs aimed at altering women's attitudes toward themselves as well as toward mathematics and math-related careers would also appear to be helpful, as would greater participation by women in "shop" and other courses providing opportunities for acquiring math-related knowledge and skill as well as for developing confidence in their performance in these areas.

Timing. Since sex differences in achievement increase most sharply after 10th grade (a major choice point in decision about how much math to take in high school), interventions prior to that time are likely to have the greatest influence. The very significant sex differences in interests already apparent by 9th grade, coupled with the importance of interests for subsequent participation and achievement, suggest that even earlier interventions are needed. The effects of science curricula and standardized testing in high school years indicate that interventions during the high school years can also be effective.

Target populations. Since socioeconomic status was related to math participation among females, females from lower SES famlies are a particularly relevant target population for intervention programs. Other groups that might be targeted for special programs are females with high ability but low career or educational aspirations, females with low self-confidence, and females with low levels of knowledge of math-related careers. The strength of the relationship between fathers' characteristics and daughters' math participation in high school suggests that women from single-parent (i.e., mother only) families may also be an important target group.

The results of this study also suggest a number of areas where additional information would be of value in clarifying and extending our understanding of the origins of sex differences in math achievement in high school. These areas include:

- information on factors that affect the career interests and plans of young women (a sizeable amount of prior research needs to be synthesized with the present findings);
- information on factors that affect the educational aspirations of young women;
- further study of the role of self-confidence in math participation and of factors that affect self-confidence in young women; and
- study of factors that influence interest in math prior to 9th grade.

A number of more specific investigations were also suggested by the findings from this study. These include studies of how counseling affects math participation in high school, of the processes by which fathers' characteristics relate to daughters' math participation levels, and of the relationships between standardized testing or advanced science curricula and female math participation.

Because there are some limits on the conclusions that can be drawn from correlational studies such as the one here reported, more truly experimental studies would also be of value. A number of such studies, testing the effects of specific interventions against appropriate control conditions, are now in progress. Such studies can test directly the causal links implied in correlational findings.

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LONG-TERM CONSEQUENCES OF SEX DIFFERENCES IN HIGH SCHOOL MATHEMATICS EDUCATION

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LONG-TERM CONSEQUENCES OF SEX DIFFERENCES IN HIGH SCHOOL MATHEMATICS EDUCATION

It's no secret that the income levels of American men and women are grossly unequal. The latest figures from the U.S. Department of Labor show that in 1975 the national median income was $12,770 for fully employed men, and $7,531 for fully employed women. The gap was even greater among people with college educations. In this group, men earned a median income of $17,891 compared to $10,861 for women (U.S. Dept. of Labor, 1976).

One explanation for these large differences in salaries has to do with the kinds of jobs held by men and women. Males in this country work in a wide range of careers, including the mechanical and technical trades and the higher-paying professions of law, medicine, business management, science, architecture, and engineering. In recent years, increasing numbers of women have begun to enter these fields. But most female professionals are still clustered in a small number of lower-paying occupations such as teaching, nursing, and social work. The extent of this occupational segregation can be seen in many areas. For example, in 1970 only one percent of the engineers, two percent of the computer specialists, sixteen percent of the physical scientists, and twenty percent of the biological scientists were women (U.S. Bureau of the Census, 1973).

It's important to note that the most heavily male-dominated professions require training in college-level mathematics. The lack of such training is undoubtedly one of the reasons why there are so few women in these fields. According to a 1978 report on high school seniors from the College Entrance Examination Board, about 63 percent of last year's college-bound males had taken four or more years of high school mathematics, while only 43 percent of the females were similarly prepared (Admissions Testing Program of the College Board, 1978). Similar findings have been reported by colleges all across the country. Quite simply, this means that more than half of today's young women are reaching college unprepared to take the math courses required for entrance into many of the higher-paying careers!

This situation has created concern among educators and researchers at many levels and recently led the National Institute of Education to fund a special series of studies on the role of mathematics in women's education and career development. This paper reports the results of one of those studies: the Project TALENT Women and Mathematics Study conducted by the American Institutes for Research (AIR). The basic questions asked by this study were (1) what accounts for the differences between men and women in high school mathematics achievement, and (2) how do these differences affect later career development?

The first half of the study focused on sex differences in participation in high school mathematics courses and in high school mathematics achievement. The results of that portion of the study were reported in a paper given earlier today (Steel, 1979). The present paper reports the findings from the second half of the study--the investigation of sex differences in the pursuit of mathematics-related careers subsequent to high school. This part of the study was organized around the following four questions:

1. To what extent were sex differences in the development of math-related careers reflected in sex differences along the educational paths leading to such careers?
2. How important and accurate were early career plans with respect to the development of math-related careers?
3. To what extent was high school math achievement predictive of success in the pursuit of math-related career goals?
4. To what extent can differences in the proportions of males and females entering math-related careers be explained by differences in our moderator variables?

Background

Sex Differences in Math Achievement

Sex-related differences in math achievement have been reported again and again in the research literature. Some researchers have called the differences "overwhelming" (Mullis, 1975), while others have described them as "minimal" (Fennema & Sherman, 1977a). The latter have suggested that there may be no real sex differences in math aptitude, and that many of the reported differences in achievement result from a failure to control for the number and nature of math courses taken by students in the various studies.

Several of the findings, however, suggest differences that are too large to dismiss without further investigation. In an analysis of data on students from the Educational Testing Service Growth Study, Hilton and Berglund (1974) found significant sex differences in math achievement favoring males. These differences began for academic students in Grade 7 and for nonacademic students in Grade 11.

One of the most frequently suggested contributors to sex differences in math achievement is the sex role socialization of males and females, The major research in this area has been summarized by Fox (1976). Mathematics has often been described as a "male domain" (Aiken, 1975; Astin, 1974; Fennema & Sherman, 1977a). Precisely when and where such stereotyping begins is a matter of debate. Stein and Smithells (1969) gave evidence that students did not consider math a "masculine" subject until they reached adolescence. Fennema (1976) found that female high school students denied that math was a sex-stereotyped subject, yet behaved as though math were for males by their avoidance of elective math courses. Horner (1972) suggested that females were motivated to avoid success in traditionally "male" areas such as math. Aiken (1975, 1976) suggested that sex differences in math ability were partially a consequence of same-sex modeling by girls, who had few female role models for success in mathematics, and Maccoby and Jacklin (1974) concluded that same-sex models were the most potent for stimulating imitative behavior; hence, girls tended to imitate their verbally-oriented mothers, while boys emulated their quantitatively-oriented fathers.

A related factor that may underlie sex differences in math achievement is the perceived usefulness of math for later careers, which Haven (1972) found to be one of the most significant predictors of decisions by gifted high school girls to take or not take elective math courses. Haven found the girls less likely than their male counterparts to perceive math as relevant to their career goals. Fennema and Sherman (1977b) also found that the perceived usefulness of math was related to the election of math courses. In addition, they found significant sex differences in achievement in schools where there were also significant sex differences in the perceived usefulness of math. These differences in perceived usefulness may reflect the different career orientations of males and females (Fox, 1976) or they may result from a lack of sufficient information. Fennema and Sherman (1977b) suggested that girls were unaware that mathematics was relevant to many careers besides purely scientific ones.

The Development of Math-Related Careers

A large number of studies of the development of science careers have consistently found mathematics to be of critical importance. (See Rever, 1973, for a review of many such studies.) Several studies have examined the characteristics of scientists (primarily male scientists) when they are well along in their careers. (See, for example, the works of Roe, 1951a, 1951b, 1953). Of greater relevance for today's young women, however, are studies of the characteristics in high school of women who later became scientists. Astin (1970) used TALENT follow-up data on young women who had been in the 12th grade in 1960 to find predictors of their career plans five years after high school. She found that scholastic aptitude (particularly mathematics) and SES were the best predictors of plans for science, "professional," and teaching careers and that traditionally masculine interests and aptitudes differentiated women planning scientific and "professional" careers from those choosing teaching, the health fields, and office work. Analyses of these women's post-high school experiences emphasized the importance of additional education and marital status as predictors of women's career decisions.

Procedures

The present study is based on a nationally representative sample of men and women now in their mid-30s who were tested as part of Project TALENT in 1960. The study was divided into two phases. Phase I used data on a subset of the 1960 TALENT participants who were tested and surveyed both in 1960 (as 9th graders) and in 1963 (as 12th graders) to examine factors influencing math gains during high school. Phase II used the data on the TALENT participants who were tested as 12th graders, including data gathered in follow-up surveys conducted one, five, and eleven years after high school. Table 1 shows how the data analyzed in the present study fit into the TALENT data collection schedule as a whole.

Samples

The procedures used to select the original sample of TALENT participants are described in detail in Chapter 2 of The Project TALENT Data Bank Handbook (Wise, McLaughlin, & Steel, 1977). Briefly, a cluster sampling approach was used with American high schools as the primary sampling unit.

TABLE 1

Modal Age of Respondents in Relation to TALENT Data Collection Schedule

Data Collection Date	High School Class				Data Collection Effort
	1960	1961	1962	1963	
1960	17½	16½	15½	14½	Initial Testing
1961	19				
1962		19			
1963			19	17½[a]	1-Year Follow-Up
1964				19	
1965	23				
1966		23			
1967			23		5-Year Follow-Up
1968				23	
1969					
1970					
1971	29				
1972		29			
1973			29		11-Year Follow-Up
1974				29	
1975					

Note. All dates are for the Fall except the 1960 testing which was in the Spring.

a. Approximately 7,500 students retested as high school seniors.

All American high schools were stratified by geographic region (8 USOE regions with the 5 largest cities treated separately), by type of school (private, parochial, or public with the public schools divided into 4 groups based on enrollment) and by retention ratio (the ratio of graduates to 10th graders). Within each of the cells thus defined, schools were selected randomly, with 1/12 of the large public schools, 1/50 of the very small public schools, and 1/20 of all other schools being chosen. Approximately 93% of the schools so chosen agreed to participate in the study. All of the students, in each of the 987 participating schools, were included in the TALENT probability sample, a total of over 375,000 students, (Approximately 65,000 additional students in special supplemental samples were also tested.)

The analyses reported in this paper are based on the TALENT 12th grade "complete data" sample. This sample consists of 12,759 of the TALENT participants tested as 12th graders, who supplied data in all three follow-up surveys. This sample heavily overrepresents the more academically able students in the original TALENT sample since they were significantly more likely to respond to the follow-up surveys. In one sense this oversampling is advantageous to the present study, which concerns careers that require high levels of academic skills. However, it is also essential that this sample be weighted so that estimates of national norms can be produced where appropriate.

Several steps were taken to generate appropriate case weights and assure their accuracy. Each of the follow-up surveys included an intensive follow-up sample of roughly 2,500 participants from each grade cohort who failed to respond to the mail survey. The intensive sample cases were tracked down and interviewed by telephone. In general, over 90% of the intensive sample members were located, and interviews were obtained from over 90% of those located. In addition to adjusting the weights to reflect this subsampling of nonrespondents, the TALENT staff developed statistical corrections for the small amount of nonresponse in these intensive samples. (See McLaughlin, Fulscher, & Yen, 1974.) These weights have been shown to eliminate virtually all known bias (Wise, 1977; Abeles & Wise, 1978). Finally the "complete data" cases were stratified by sex, race, 12th grade academic aptitude, socioeconomic status, and 11-year post-high school occupation group, and their weights further adjusted to reflect differences in completion rates between the various cells in this design.

Study Variables

The variables analyzed in the second phase of this study are questionnaire items and test scores selected from the following sources:

- the 1960 student questionnaire and test battery,
- the 1960 school characteristics questionnaire,
- the 1-year follow-up questionnaire for the 12th grade cohort,
- the 5-year follow-up questionnaire for the 12th grade cohort, and
- the 11-year follow-up questionnaire for the 12th grade cohort.

The Project TALENT Data Bank Handbook (Wise, McLaughlin, & Steel, 1977) includes a description of each of the tests and reproductions of each of the questionnaires.

The following variables are of particular importance in the findings reported here:

Math achievement. The math achievement measure used in this study was a 54-item test including 16 "word problem" items designed to measure arithmetic reasoning, 24 introductory math items primarily covering elementary algebra and number theory, and 14 advanced math items covering topics generally taught in grades 10 through 12 including plane geometry, analytic geometry, trigonometry, and elementary calculus.

Math participation. The measure used was the number of semesters of high school mathematics reported on in the 1960 Student Information Blank.

Math level of careers and career plans. Some initial analyses were done in defining the math level of careers or career plans. Three indicators of the amount of college and high school math typically taken by those in each career were developed. Table 2 shows these indicators and the resultant classification of careers into 6 levels of math. Careers at levels 4, 5, and 6 mostly require some college math and so are grouped together and labeled "math-related" careers in some analyses. Careers at level 3 generally require college participation and may require some statistics but do not require calculus or other college math. They are used as an "intermediate" level in many analyses to provide a comparison group with a level of education somewhat comparable to the "math-related careers." Level 1 and 2 careers are grouped together as low math-level careers in many of the analyses.

TABLE 2

The Math Level of Careers as Defined by Three Indicators

Career Plan (Number of cases) (1-Year Follow-Up)	Indicator		
	College Math		High School Math
	(% in 1st year math & earning high grades)	(% taking or planning to take college math)	(% taking more than 2 years)
Level 6 (requires graduate level mathematics):			
Mathematician (36)	88	92	92
Level 5 (generally requires advanced college mathematics):	*		
Engineer (682)	76	87	90
Physical Scientist (184)	75	90	92
Architect (73)	71	88	77
Pilot (13)	69	92	85
Level 4 (generally requires introductory college mathematics):	*		
Pharmacist (70)	65	87	80
Dentist (68)	63	79	87
Physician (264)	61	87	89
Biological Scientist (109)	59	86	75
Armed Forces Officer (38)	59	72	87
Level 3 (requires college and may require some statistics):	*		
Forester (38)	45	68	61
Lawyer (183)	43	67	84
College Professor (73)	48	62	77
Engineering Aide (15)	43	57	67
Medical/Dental Technician (145)	40	58	50
Accountant (402)	40	48	55
High School Teacher (1427)	39	57	62
Elementary Teacher (587)	40	57	54
Sociologist/Psychologist (97)	34	70	68
Political Scientist/Economist (80)	32	48	74
Businessman (398)	33	51	58
Librarian (22)	36	55	59
Clergyman (106)	34	49	55
Writer (94)	26	45	62
Social Worker (95)	25	46	47
Level 2 (generally requires some high school level mathematics):		*	
Nurse (490)	7	9	50
Salesperson (97)	22	31	51
Policeman/Fireman (58)	4	19	41
Armed Forces Enlistedman (73)	15	29	51
Artist/Entertainer (160)	6	23	41
Farmer (187)	18	31	34
Skilled Worker (418)	10	12	49
Structural Worker (82)	12	15	38
Level 1 (generally requires little or no mathematics):			*
Secretary/Office Worker (972)	6	8	17
Barber/Beautician (173)	1	1	14

*Denotes gap in indicator values that were used in differentiating the 6 groups.

Math level of college majors. College majors were classified into the same 6 math levels used in classifying careers. In some analyses, the 6 levels were collapsed into three groups, math-related, intermediate math level, and low math level, analogously to the career categories.

Career interests. A 205-item interest inventory with 17 scales was administered in 1960 and 1963. The primary scales used in the present study were "Physical Science, Math, and Engineering Interest" and "Interest in Office Work." In addition, four items relating specifically to mathematics were combined to form a measure of interest in math itself.

Expected career at ages 18, 19, and 23 and actual occupation at age 29. In the 12th grade the participants were asked to mark the one of 35 fixed options that was closest to their expected career. These options and their groupings into math levels are shown in Table 2. In the follow-up surveys, the participants were asked to name their actual or planned occupations. The free responses were coded into one of several hundred categories. For this study the occupations were grouped into the same six math levels shown in Table 2.

Findings

The complete findings of the Project TALENT Women and Mathematics Study are reported in detail in the project's technical report to the National Institute of Education, which is currently undergoing final revisions. The findings from the first part of the study (reported earlier today in a paper by Steel) will be summarized very briefly here. The key findings were:

1. Girls and boys differed only very slightly in 9th grade math achievement scores. During high school, however, the average increases in math achievement scores for boys were roughly twice the size of the increases for females, resulting in very substantial sex differences in 12th grade math achievement scores.
2. *Virtually all of the sex differences in 12th grade math achievement could be explained in terms of sex differences in the number of math courses taken in high school*.
3. The number of mathematics courses taken during high school was predicted most strongly by mathematics achievement and educational expectations in 9th grade--measures on which only minimal

sex differences were found. Among students of equal ability and educational aspirations, 9th grade levels of interest in mathematics and in math-related careers predicted how much high school math a student would take. *Virtually all of the sex differences in the number of mathematics courses taken in high school could be explained by differences in career interests already evident in the 9th grade*.

The major findings for the second phase of the study are presented here in terms of the three major questions addressed.

1. *To what extent were sex differences in the development of math-related careers reflected in sex differences along the educational paths leading to such careers?*

The second phase of the study examined factors that affected the development of math-related careers during the period from 12th grade through age 29. In this phase, math-related careers were defined as those careers generally requiring some college-level math. These are the careers shown under levels 4, 5, and 6 in Table 2 above.

Since the math-related careers studied require, by definition, at least some college, the first step in examining sex differences in the development of math-related careers was to analyze sex differences in educational attainment and in the relationship between educational attainment and entry into math-related careers. Figure 1 shows the educational paths followed by the males and females in the TALENT 12th grade cohort. The proportions in Figure 1 were estimated from the 12,759 "complete data" cases in the 12th grade cohort using case weights that provide unbiased estimates of norms for all 1960 12th graders.

The results show that the proportion of 12th grade males planning to go to college was higher than the proportion of females (54% compared to 39%), but that the males with college plans were somewhat less likely to be in college one year later than females with college plans (66% compared to 75% for females with college plans). Overall the proportion of males in college one year after high school was only slightly larger than the proportion of females (41% compared to 37%). By five years after high school, the proportion of females and males having completed college were similar (26% and 22% respectively), but roughly twice as many males as females had gone on to graduate school. Between five and eleven years after high

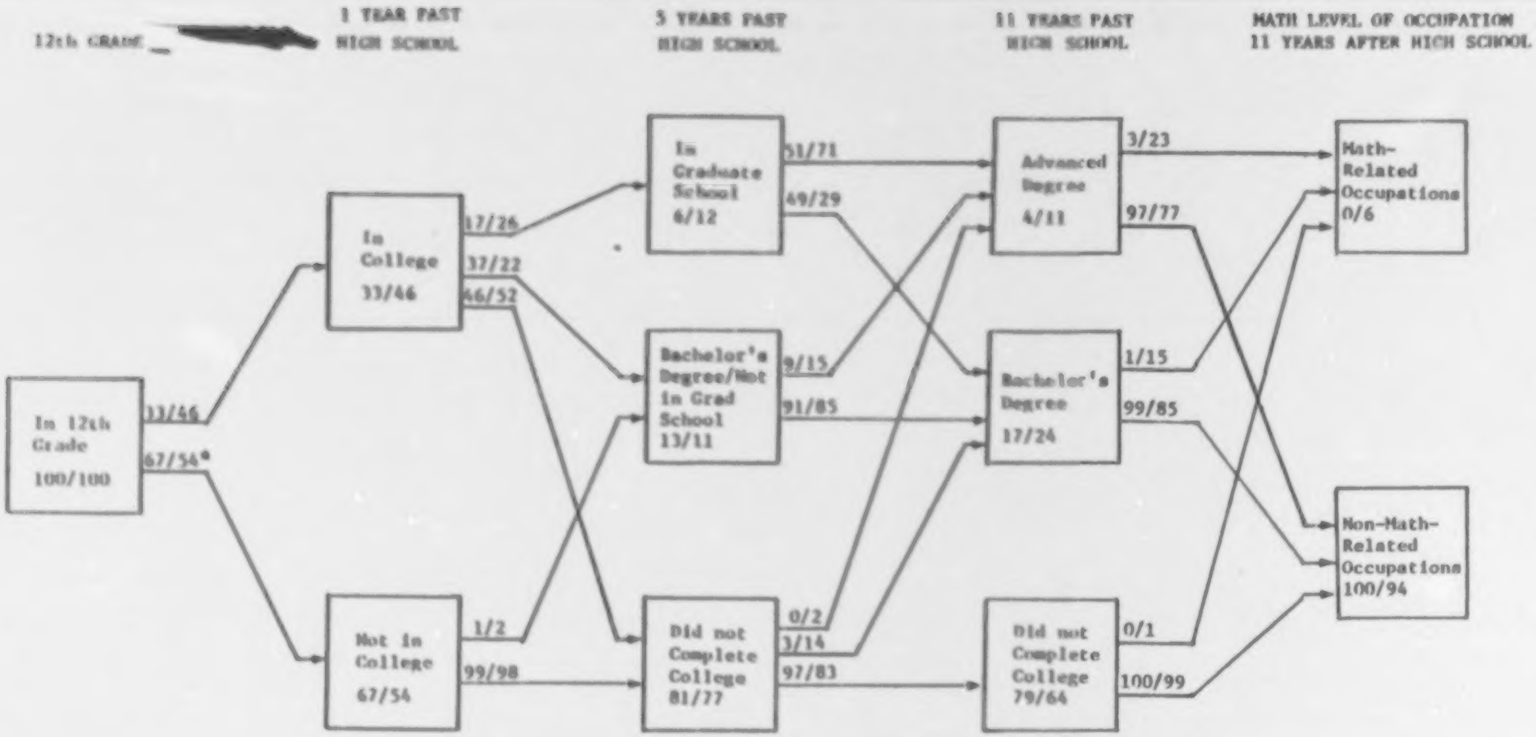

Figure 1. Educational paths to math-related careers

NOTE: The numbers in each box are the percentages of all females/males from the Class of 1960 who were in the category shown at the indicated time. The numbers along the lines are the percentages of females/males from the adjacent category who had moved to the indicated category by the time of the next follow-up survey. The percentages are based on 12,759 cases from the Project TALENT Class of 1960 sample. Case weights were used to eliminate bias in extimating national norms.

school, 18% of the males who had not previously completed college did so compared to only 4% of the females who had not previously completed college. By age 29 sex differences in educational attainment were quite significant. In addition, even controlling for sex differences in educational attainment, males were much more likely to have followed an educational course leading to a math-related career. Only 1% of the females with a bahcelor's degree but not an advanced degree went into math-related careers compared to 15% of the males in this category. Similarly, only 3% of the females with advanced degrees went into math-related careers compared to 23% of the males with advanced degrees.

The findings indicate that sex differences in educational attainment can account for a portion of the sex difference in the math level of occupation at age 29. Much more striking, however, are the very large sex differences within each level of education. Sex differences in the establishment of math-related careers are clearly much more than just a reflection of general sex differences in educational attainment.

2. How important and accurate were early career plans with respect to the development of math-related careers?

The second question concerning the development of math-related careers dealt with career planning. How essential was early career planning to eventual entry into math-related careers? How successful were those who planned, in high school, to enter a math-related career?

For these analyses, three levels of career plans were investigated: careers generally requiring college-level math; other careers generally requiring some college; and other careers that do not generally require college. Individuals with no specific career plan or no specific occupation at age 29 were excluded from the analysis, as were those reporting no plan or occupation outside the home, in order to make the remaining groups more comparable. Table 3 shows the relationship between career plans in 12th grade, one year later, five years later, and occupation at age 29.

The results indicate that a relatively low proportion of those who planned to enter a math-related career actually did so. More than 80% of the males and 90% of the females who planned math-related careers in 12th grade were in other kinds of careers at age 29. Even at age 19, when most of those planning science careers had completed a year of college, only a quarter of those who planned math-related careers were in math-related

TABLE 3

Occupational Outcome at Age 29 for each Level of Career Plan at Ages 18, 19, and 23

	% in Low Math-Level Careers		% in Intermediate Math-Level Careers		% in Math-Related Careers	
	Male	Female	Male	Female	Male	Female
Age 18 Career Plans						
Low Math-Level	85	80	15	20	0.6	0.0
Intermediate Math-Level	44	39	53	60	3.1	0.2
Math-Related	39	54	43	38	17.7	7.7
Age 19 Career Plans						
Low Math-Level	82	81	16	19	1.9	0.0
Intermediate Math-Level	34	31	63	69	3.4	0.3
Math-Related	31	18	43	57	25.7	24.7
Age 23 Career Plans						
Low Math-Level	87	87	13	13	0.5	0.0
Intermediate Math-Level	30	22	67	78	3.0	0.7
Math-Related	26	16	26	47	48.0	37.2

careers at age 29. (Note, too, that homemakers at age 29 were excluded.) Even at age 23, only half of those who planned math-related careers were successful in carrying out these plans.

The second finding concerning math-related career plans was that *virtually no one who was not already planning a math-related career by 12th grade later switched into a math-related career by age 29*. Even among those who were planning college-related but not math-related careers, only 3% of the males switched into math-related careers. This finding and the fact that over one-third of those planning math careers in 12th grade had changed to other career plans one year later indicate that there are important early selection factors for math-related careers that both screen out a significant number of students initially planning math-related careers and make it difficult for others to later change into a math-related career path.

3. *To what extent was high school math achievement predictive of success in the pursuit of math-related career goals?*

By 12th grade, a strong relationship between math achievement and plans regarding math-related careers is evident. The third area of investigation concerned the relationship between high school math achievement and the *realization* of plans to enter math-related careers made at various points in time. The data presented in Table 3 show clearly that a significant proportion of those planning math-related careers are not working in math-related careers at age 29. The goal of these analyses was to determine the extent to which a failure to develop math skills in high school could account for their lack of success in meeting career goals.

Table 4 shows the mean math achievement scores of TALENT participants with various levels of math-related career plans in 12th grade who did or did not enter a math-related career. Those who were successful in their pursuit of a math-related career had had dramatically higher math achievement scores in 12th grade. Those who were not planning math-related careers in 12th grade but later entered a math-related career also had markedly higher 12th grade achievement scores than their counterparts who did not switch into math-related careers, indicating the importance of math skills for keeping career options open even if a math-related career is not explicitly planned.

TABLE 4

Mean 12th Grade Math Achievement* by Math Levels of 12th Grade Career Plan and Occupation at Age 29

Math Level of Occupation at Age 29	Mathematics Level of 12th Grade Career Plan			
	Some College Level Math	May Require Some Statistics	High School Math Only	Plan Not Classified
MALES				
Some college Level Math	1.23±.08 (509)	.69±.22 (78)	.42±.49 (16)	.63±.35 (31)
May Require Some Statistics	.83±.06 (931)	.34±.06 (1118)	-.17±.14 (195)	-.06±.13 (239)
High School Math Only	.27±.08 (583)	-.11±.08 (610)	-.47±.07 (691)	-.46±.10 (373)
Not Classified	.70±.13 (242)	.29±.16 (149)	-.39±.23 (70)	-.17±.26 (58)
Total	.76±.04 (2265)	.21±.04 (1955)	-.39±.06 (972)	-.25±.07 (701)
FEMALES				
Some College Level Math	1.29±.42 (21)	1.02±.74 (7)	.48±1.39(2)	1.25±.74 (7)
May Require Some Statistics	.96±.20 (97)	.25±.07 (820)	-.39±.12 (286)	-.06±.14 (194)
High School Math Only	-.05±.29 (46)	-.26±.11 (323)	-.62±.06 (926)	-.58±.12 (249)
Not Classified	.60±.16 (151)	-.01±.06 (1244)	-.58±.05 (1692)	-.47±.07 (752)
Total	.66±.11 (315)	.05±.04 (2394)	-.57±.04 (1906)	-.41±.06 (1202)

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* In standard score units (with numbers of cases in parentheses) with approximate 95% confidence bounds.

Table 5 shows the same results for career plans held at approximately age 23. These results are somewhat more surprising. By age 23 nearly all of those who were planning math-related careers had completed their undergraduate education and either gone on to graduate school or entered the labor force. It would have been reasonable to suppose that skills developed during high school would be relatively unrelated to success in the development of math-related careers between age 23 and age 29. Yet those who were successful in entering math-related careers had average 12th grade math scores roughly .3 standard deviations greater than those who entered careers not requiring college math and over .7 standard deviations higher than those who were in careers requiring little or no math at all. The relationship between high school math achievement and switching into a math-related career not planned at age 23 was even more dramatic. Those switching into math-related careers had 12th grade math scores averaging .9 standard deviations greater than those ending up in an intermediate level career.

One plausible explanation for the relationship of high school math achievement to career development after age 23 is that high school math achievement is related to events after high school which moderate the relationship of math achievement to later career development. Two potential moderators, educational attainment at age 23 and the math level of college major, were examined. For each moderator, an analysis of variance was run to test the relationship of 12th grade math achievement to math level of occupation at age 29 when both the math level of the career plan at age 23 and the moderator were controlled. This approach is a somewhat novel application of analysis of variance, since the "dependent" variable--12th grade math achievement--predates all of the "independent" variables. The procedure was not used to measure the extent to which the control variables predict math achievement but only to measure whether individuals in the groups defined by the control variables differed significantly in terms of 12th grade math achievement. In particular, the question of primary interest is whether individuals who planned careers at the *same* math level at age 23 and had completed the *same* level of education (or had completed majors at the same math level) but ended up in occupations at age 29 at *different* math-levels were consistently different in terms of their 12th grade math achievement scores.

TABLE 5

Mean 12th Grade Math Achievement by Math Levels of Career Plan at Age 23 and Occupation at Age 29

Math Level of Occupation at Age 29	Mathematics Level of Career Plan at Age 23			
	Some College Level Math	May Require Some Statistic	High School Math Only	Plan Not Classified
MALES				
Some College Level Math	1.18±.09 (523)	1.03±.23 (75)	.50±.54 (13)	.38±.41 (23)
May Require Some Statistics	.91±.13 (224)	.49±.05 (1776)	-.02±.12 (246)	.15±.13 (237)
High School Math Only	.45±.16 (158	.10±.09 (518)	-.35±.06 (1185)	-.29±.10 (396)
Not Classified	.82±.19 (102)	.66±.15 (174)	-.16±.19 (104)	-.05±.17 (139)
Total	.97±.06 (1007)	.44±.04 (2543)	-.28±.05 (1584)	-.09±.07 (705)
FEMALES				
Some College Level Math	1.27±.38 (26)	1.05±.65 (9)	------ (1)	------ (1)
May Require Some Statistics	.87±.38 (27)	.21±.06 (1070)	-.37±.19 (105)	-.20±.14 (195)
High School Math Only	.89±.80 (6)	-.20±.14 (191)	-.50±.07 (757)	-.68±.08 (590)
Not Classified	1.18±.37 (28)	.16±.06 (1058)	-.42±.07 (725)	-.57±.04 (2028)
Total	1.09±.11 (87)	.16±.04 (2328)	-.45±.05 (1588)	-.57±.04 (2814)

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* In standard score units (with numbers of cases in parentheses) with approximate 95% confidence bounds.

Table 6 shows the ANOVA results when educational attainment at age 23 is controlled. This analysis was inclusive in that individuals who were not planning careers outside the home at age 23 or were not working outside the home at age 29 were included as a separate category. The differences by outcome group were statistically significant, although modest in a practical sense. The inclusive nature of the analyses undoubtedly introduced some noise into the statistics, as decisions regarding homemaking or unemployment are likely to be independent of ability. Those who did end up in a math-related career had averaged between .25 and .35 standard deviations higher on 12th grade math achievement than those who ended up with careers at the intermediate level.

Table 7 shows the ANOVA results when the math level of college major is controlled. For contrast, this analysis was exclusive, limited to college attenders who planned careers outside the home at age 23 and were working outside the home at age 29. Again 12th grade math achievement was significantly related to occupational outcome at age 29 even after career plan at age 23 and college major were controlled. Those who did end up in math-related careers had averaged more than .3 standard deviations higher on the 12th grade math achievement test than those who had the age 23 career plans and a college major at the same level but ended up in another college-related career.

4. To what extent can differences in the proportions of males and females entering math-related careers be explained by differences in moderator variables?

The tables and figures presented above indicate that individuals entering math-related careers were characterized by:

- early plans to enter math-related careers,
- high levels of educational attainment,
- the completion of math-related college majors, and
- high mathematics achievement scores in high school.

The final question addressed in the study was related to the interaction among these characteristics and the processes leading to the tremendous differences between the proportions of men and women in math-related occupations. Specifically, the importance of sex differences in high school mathematics achievement was examined in the context of the other moderator variables.

TABLE 6a

12th Grade Math Achievement (R340) by Occupation at Age 29 (DOCCMTH), Career Plan at Age 23 (CCPLNMTH), and Amount of Education at Age 23 (CAMTED)

Males

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Main Effects	238486.187	9	26498.465	349.587	0.001
DOCCMTH	3215.031	3	1071.677	14.138	0.001
CCPLNMTH	9198.355	3	3066.118	40.450	0.001
CAMTED	84919.062	3	28306.352	373.438	0.001
2-Way Interactions	2771.062	27	102.632	1.354	0.104
DOCCMTH CCPLNMTH	1360.746	9	151.194	1.995	0.036
DOCCMTH CAMTED	922.569	9	102.508	1.352	0.203
CCPLNMTH CAMTED	492.472	9	54.719	0.722	0.999
3-Way Interactions	3441.875	26	132.380	1.746	0.011
DOCCMTH CCPLNMTH CAMTED	3441.902	26	132.381	1.746	0.011
Explained	244699.125	62	3946.760	52.069	0.001
Residual	419321.625	5532	75.799		
Total	664020.750	5594	118.702		

5893 cases were processed.
298 cases (5.1 percent) were missing.

Grand Mean = 31.91
Standard Deviation = 10.90

		Unadjusted		Adjusted for Independents	
Variable + Category	N	Deviation	Eta	Deviation	Beta
Occupation at Age 29 (DOCCMTH)					
0. Unclassified	487	0.98		0.96	
1. Low Math Level	2132	-4.96		-0.75	
2. Intermediate Level	2372	1.93		-0.14	
3. Math-Related	604	9.14		2.44	
			0.41		0.09
Career Plan at Age 23 (CCPLNMTH)					
0. Unclassified	731	-3.91		-1.22	
1. Low Math Level	1467	-6.10		-1.38	
2. Intermediate Level	2446	1.87		-0.18	
3. Math-Related	951	7.61		3.54	
			0.44		0.15
Amount of Education (CAMTED)					
1. No College	1472	-8.91		-7.34	
2. Some College	1873	-0.54		-0.56	
3. Bachelor's Only	1057	4.43		3.78	
4. Some Graduate Work	1193	7.91		6.59	
			0.57		0.47
Multiple R Squared					0.359
Multiple R					0.599

TABLE 6b

12th Grade Math Achievement (R340) by Occupation at Age 29 (DOCCMTH), Career Plan at Age 23 (CCPLNMTH), and Amount of Education at Age 23 (CAMTED)

Females

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Main Effects	192497.750	9	21388.637	327.636	0.001
DOCCMTH	714.364	3	238.121	3.648	0.012
CCPLNMTH	6644.293	3	2214.764	33.926	0.001
CAMTED	80471.312	3	26823.770	410.893	0.001
2-Way Interactions	6248.000	26	240.308	3.681	0.001
DOCCMTH CCPLNMTH	857.254	9	95.250	1.459	0.156
DOCCMTH CAMTED	1018.542	8	127.318	1.950	0.048
CCPLNMTH CAMTED	3195.337	9	355.037	5.439	0.001
3-Way Interactions	1729.062	19	91.003	1.394	0.117
DOCCMTH CCPLNMTH CAMTED	1729.104	19	91.005	1.394	0.117
Explained	200474.812	54	3712.496	56.869	0.001
Residual	421001.687	6449	65.282		
Total	621476.500	6503	95.568		

6817 cases were processed.
313 cases (4.6 percent) were missing.

Grand Mean = 25.93
Standard Deviation = 9.78

		Unadjusted		Adjusted for Independents	
Variable + Category	N	Deviation	Eta	Deviation	Beta
Occupation at Age 29 (DOCCMTH)					
0. Unclassified	3680	-0.67		0.13	
1. Low Math Level	1446	-2.81		-0.49	
2. Intermediate Level	1343	4.44		0.07	
3. Math-Related	35	16.47		3.66	
			0.28		0.04
Career Plan at Age 23 (CCPLNMTH)					
0. Unclassified	2697	-3.33		-0.83	
1. Low Math Level	1485	-1.99		0.32	
2. Intermediate Level	2238	4.76		0.46	
3. Math-Related	84	15.31		8.86	
			0.41		0.12
Amount of Education (CAMTED)					
1. No College	3071	-5.00		-4.57	
2. Some College	1499	0.87		0.90	
3. Bachelor's Only	1275	6.38		5.85	
4. Some Graduate Work	659	8.96		7.92	
			0.54		0.49
Multiple R Squared					0.310
Multiple R					0.557

TABLE 7a

12th Grade Math Achievement (R340) by Occupation at Age 29 (DOCCMTH), Career Plan at Age 23 (CCPLNMTH), and Math Level of College Major (CMAJMTH)

Males

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Main Effects	41525.836	6	6920.973	83.528	0.001
DOCCMTH	6306.539	2	3153.270	38.056	0.001
CCPLNMTH	1602.433	2	801.217	9.670	0.001
CMAJMTH	9490.969	2	4745.484	57.272	0.001
2-Way Interactions	778.066	13	59.851	0.722	0.999
DOCCMTH CCPLNMTH	289.086	5	57.817	0.698	0.999
DOCCMTH CMAJMTH	124.588	4	31.147	0.376	0.999
CCPLNMTH CMAJMTH	320.796	4	80.199	0.968	0.999
3-Way Interactions	320.152	7	45.736	0.552	0.999
DOCCMTH CCPLNMTH CMAJMTH	320.153	7	45.736	0.552	0.999
Explained	42624.062	26	1639.387	19.785	0.001
Residual	248077.875	2994	82.858		
Total	290701.937	3020	96.259		

5908 cases were processed.
2887 cases (48.9 percent) were missing.

Grand Mean = 35.89
Standard Deviation = 9.81

Variable + Category	N	Unadjusted Deviation	Unadjusted Eta	Adjusted for Independents Deviation	Adjusted for Independents Beta
Occupation at Age 29 (DOCCMTH)					
1. Low Math Level	686	-3.29		-2.46	
2. Intermediate Level	1780	-0.54		0.00	
3. Math-Related	555	5.82		3.03	
			0.30		0.18
Career Plan at Age 23 (CCPLNMTH)					
1. Low Math Level	377	-4.15		-1.97	
2. Intermediate Level	186[illegible]	-1.04		-0.05	
3. Math-Related	779	4.50		1.08	
			0.29		0.09
Math Level of Major (CMAJMTH)					
1. Low Math Level	484	-1.81		-1.36	
2. Intermediate Level	1341	-2.65		-1.83	
3. Math-Related	1196	3.70		2.60	
			0.31		0.22
Multiple R Squared					0.143
Multiple R					0.378

100

TABLE 7b

12th Grade Math Achievement (R340)
by Occupation at Age 29 (DOCCMTH),
Career Plan at Age 23 (CCPLNMTH),
and Math Level of College Major (CMAJMTH)

Females

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Main Effects	10819.180	6	1803.197	22.161	0.001
DOCCMTH	826.713	2	413.356	5.080	0.006
CCPLNMTH	923.938	2	461.969	5.677	0.004
CMAJMTH	3442.708	2	1721.354	21.155	0.001
2-Way Interactions	1182.215	12	98.518	1.211	0.269
DOCCMTH CCPLNMTH	338.982	5	67.796	0.833	0.999
DOCCMTH CMAJMTH	404.561	3	134.854	1.657	0.173
CCPLNMTH CMAJMTH	440.723	4	110.181	1.354	0.247
3-Way Interactions	366.363	3	122.121	1.501	0.211
DOCCMTH CCPLNMTH CMAJMTH	366.365	3	122.122	1.501	0.211
Explained	12367.812	21	588.943	7.238	0.001
Residual	104803.500	1288	81.369		
Total	117171.312	1309	89.512		

6851 cases were processed.
5541 cases (80.9 percent) were missing.

Grand Mean = 31.60
Standard Deviation = 9.46

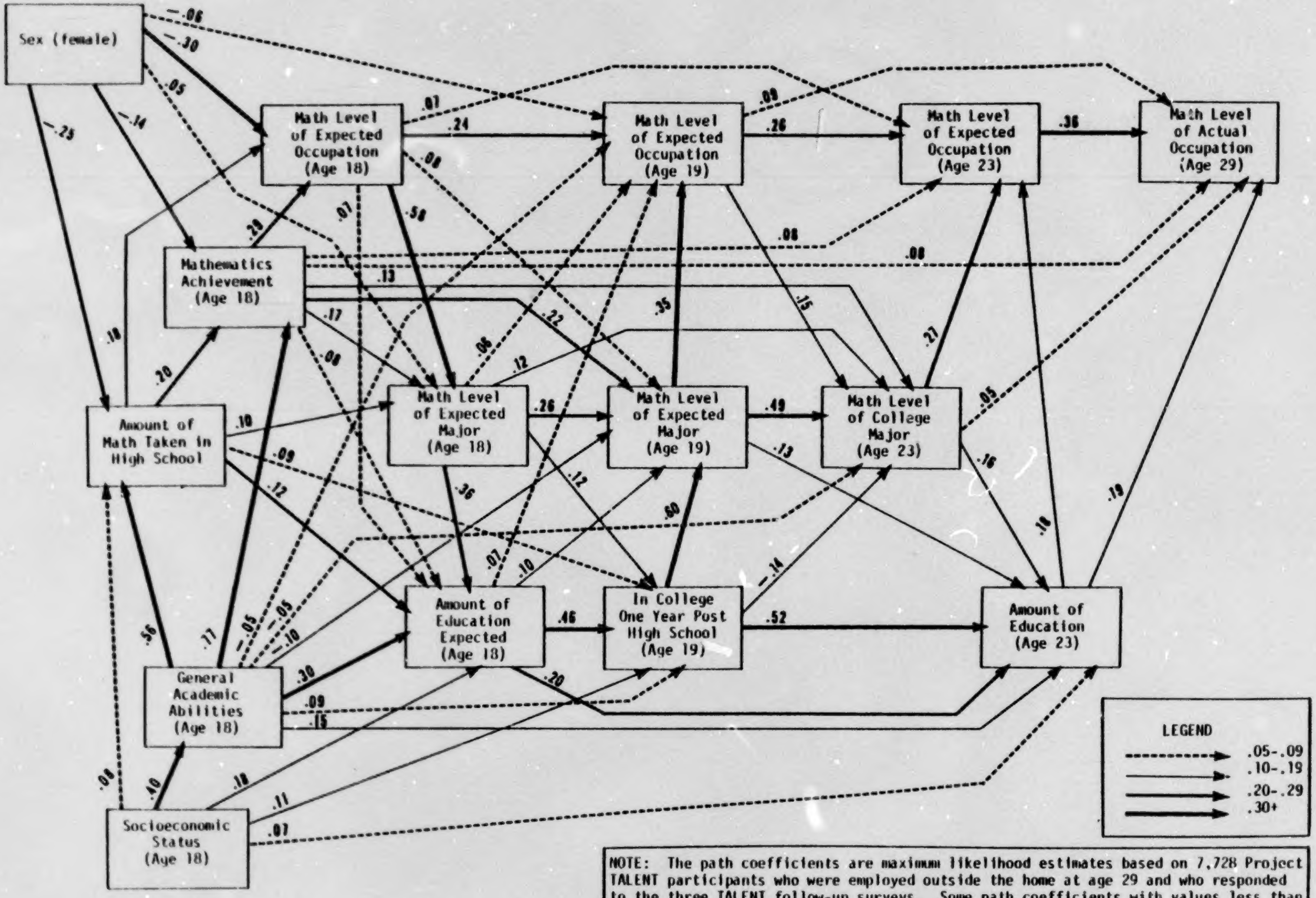
Variable + Category	N	Unadjusted Deviation	Unadjusted Eta	Adjusted for Independents Deviation	Adjusted for Independents Beta
Occupation at Age 29 (DOCCMTH)					
1. Low Math Level	299	-2.33		-1.50	
2. Intermediate Level	979	0.37		0.32	
3. Math-Related	32	10.43		4.32	
			0.21		0.11
Career Plan at Age 23 (CCPLNMTH)					
1. Low Math Level	216	-2.71		-0.91	
2. Intermediate Level	1044	0.09		-0.06	
3. Math-Related	50	9.82		5.15	
			0.23		0.11
Math Level of Major (CMAJMTH)					
1. Low Math Level	422	0.81		0.88	
2. Intermediate Level	685	-1.86		-1.48	
3. Math-Related	203	4.61		3.18	
			0.24		0.18
Multiple R Squared					0.092
Multiple R					0.304

The approach used in these analyses was to construct a causal (path) model that hypothesized relationships between the variables in terms of a set of structural equations and then examine the extent to which the correlations between all of the variables could be explained in terms of the hypothesized relationships. (See Jöreskog, 1971, for a more complete description of this approach.) The primary hypothesis tested in constructing the causal model was that sex differences in the occupational outcome measure could be explained in terms of differences in the moderator variable so that no direct path between sex and the occupational outcome variable was included.

The variables selected for this summary model included career plans, educational expectations or attainment, and expected or actual college major, each assessed at three points in time (roughly ages 18, 19, and 23). This approach provides two advantages. First, it allows for the examination of effects of math achievement at different points in career development. It is thus possible to identify points at which interventions may be more effective. The second advantage is that it allows for the identification of variables relating to change. When career plan at age 19 is used as a predictor of career plan at age 23, the other predictors are in effect predicting career plan at age 23 above or below expectations based on career plan at age 19.

The use of causal models does not, of course, prove anything about causation. We can eliminate models that are in conflict with empirical data and we can show that a particular model is consistent with the observations, but there will always be a number of alternative models that might be equally plausible, and the results might change substantially if data on new variables were included. The computer algorithm used to generate estimates of the path coefficients, LISREL IV (Jöreskog & Sörtom, 1978) also provides a chi-square statistic that gives us the approximate probability of obtaining discrepancies between the observed and predicted correlations as large as those actually observed. For the path model shown in Figure 2, the probability level was .09, meaning that there was one chance in ten of obtaining discrepancies as large as those observed by chance alone. Thus the model is not rejected by the data, even at the .05 level of significance.

Figure 2 shows the causal model that was finally adopted. (The fact that a sequence of 5 or 6 models were tried and adjusted opens the signifi-


Sex (female)
Math Level of Expected Occupation (Age 18)
Math Level of Expected Occupation (Age 19)
Math Level of Expected Occupation (Age 23)
Math Level of Actual Occupation (Age 29)
Mathematics Achievement (Age 18)
Amount of Math Taken in High School
Math Level of Expected Major (Age 18)
Math Level of Expected Major (Age 19)
Math Level of College Major (Age 23)
Amount of Education Expected (Age 18)
In College One Year Post High School (Age 19)
Amount of Education (Age 23)
General Academic Abilities (Age 18)
Socioeconomic Status (Age 18)
-.06
-.30
.05
-.25
-.14
.07
.24
.08
.09
.26
.36
.28
.07
.58
.08
.08
.13
.17
.22
.15
.35
.06
.12
.27
.18
.20
.10
.26
.49
.05
.09
.13
.12
.36
.16
.12
.19
.18
.60
.07
.10
-.14
.56
.77
-.05
-.05
-.10
.30
.46
.52
.20
.09
.15
.08
.40
.18
.11
.07
LEGEND
.05-.09
.10-.19
.20-.29
.30+

NOTE: The path coefficients are maximum likelihood estimates based on 7,728 Project TALENT participants who were employed outside the home at age 29 and who responded to the three TALENT follow-up surveys. Some path coefficients with values less than .05 are not shown even though they are significantly different from 0 for a sample of this size.

Figure 2. Summary path model of the relationship of sex to math level of actual occupation at age 29

cance level to question. However, the size of the path coefficients, which are relatively stable with this very large sample, is of more direct interest than the exact significance level.) In this model, sex has primary effects on (1) the amount of math taken in high school, (2) math achievement at the end of high school, and most of all on (3) the math level of high school career expectations. The relationship of sex to high school career plans leads to large indirect effects on career plans at ages 19 and 23 and thus on occupation at age 29. High school career plans are also related to college major expectations, which have an effect on changes in career plans between high school and age 23.

High school mathematics achievement has a large effect on the math levels of career plans and college major plans. Math achievement also has a large influence on changes in college major plans between ages 18 and 19 and between ages 19 and 22 and thus has a sizable indirect effect on changes in career plans. Math achievement also has a somewhat smaller, but very significant, direct effect on occupation at age 29. Taking math courses in high school has direct effects on the amount of education expected and whether one is actually in college at age 19 and on the math level of the expected major. These effects are in addition to the indirect effects through higher math achievement.

On the whole, the model shown in Figure 2 suggests that career plans and math achievement in high school are very important determinants of the math level of one's career at age 29. Sex differences in the outcome measures appear to develop almost entirely through differences in these two variables.

Summary and Conclusions

The goal of this study was to identify factors that were important in the development of math-related careers, particularly those factors that have screened out a disproportionate number of women. The main focus was on the role of achievement in mathematics during high school, which has been suggested to be a critical barrier for women.

The findings emphasize the importance of early planning for math-related careers. Very few of those who were not planning a math-related career in 12th grade later switched into a math-related career. Math skills were, of course, highly correlated with math-related career plans, but they were also an important predictor of success in carrying out math-related career plans. Similarly, math skills developed during high school were both an essential component of subsequent educational attainment and a significant predictor of success in establishing math-related careers independent of level of educational attainment. High school math achievement played a significant role in the development of math-related careers over the entire period from high school to age 29.

Only minimal sex differences in math achievement were observed in 9th grade, but dramatic sex differences were measured in math achievement gains during the high school years. These differences were attributable to a greater participation by males in elective math courses and a greater male interest in math-related careers. This suggests that high school is the most important point of intervention for reducing female disadvantagement in math achievement and that a reduction can be accomplished by increasing the number of math courses that females take during high school.

The results of this study point out the vital importance of early interests and plans in the development of math-related careers. Sex differences in interest in and planning for math-related careers were found to clearly precede differences in math achievement. If females are to maintain their options for pursuing math-related careers, it is important that emphasis be given to career education prior to high school.

The primary policy implication of this study is that greater attention should be given to career exploration prior to high school and to mathematics education during high school in order to reduce a major component of sex inequities in later occupational outcomes. It is likely that such an emphasis would be more efficient and effective than compensatory interventions such as job training programs targeted for older women. This is not to say that we need not be concerned about women today who have already failed to develop essential math skills, but only that programs aimed at preventing math deficiencies are likely to be more effective for future generations.

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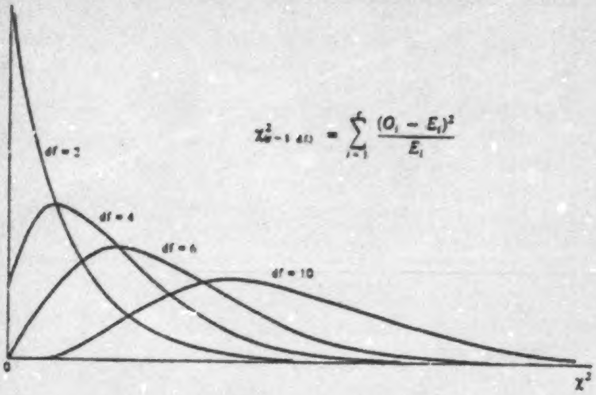
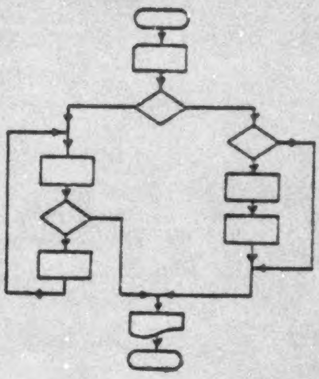
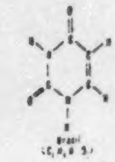
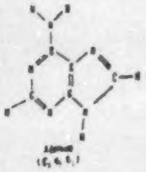


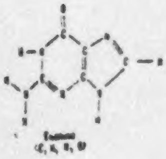
$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$









$$i\hbar\frac{\partial\Psi}{\partial t} = -\frac{\hbar^2}{2m}\nabla^2\Psi + V\Psi$$

MATHEMATICS
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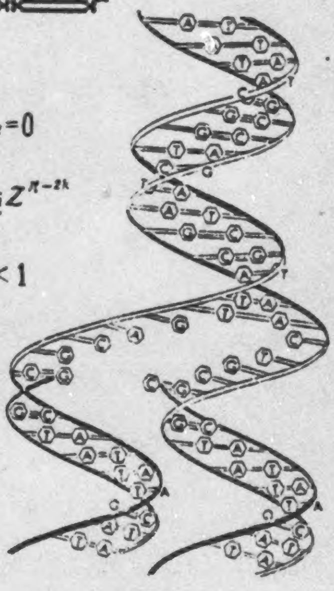
$$(1-Z^2)\frac{d^2P_n}{dZ^2} - 2Z\frac{dP_n}{dZ} + n(n+1)P_n = 0$$

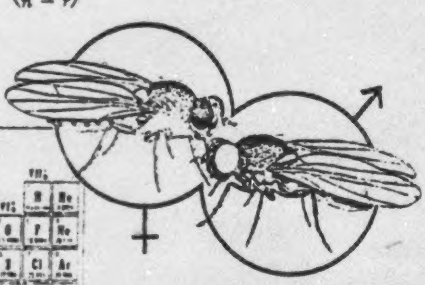
$$P_n(Z) = \sum_{k=0}^{N}\frac{(-1)^k(2n-2k)!}{2^n k!(n-k)!(n-2k)!}Z^{n-2k}$$

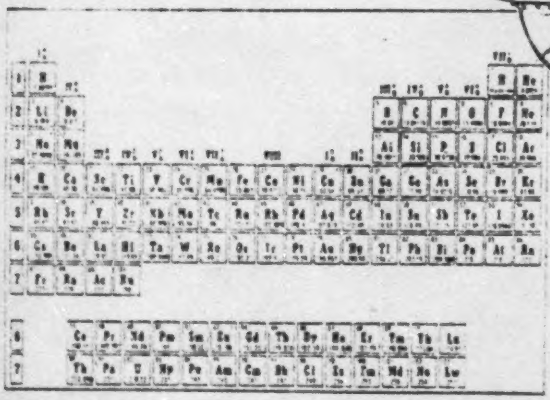
$$\frac{1}{\sqrt{1+t^2-2tZ}} = \sum_{n=0}^{\infty} t^n P_n(Z);\ |t|<1$$

1
1 1
1 2 1
1 3 3 1
1 4 6 4 1
1 5 10 10 5 1
1 6 15 20 15 6 1

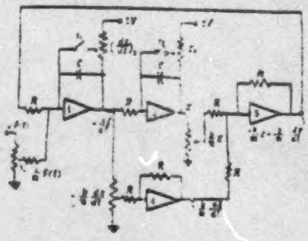
$$\binom{n}{r} = \frac{n!}{r!(n-r)!} \qquad \binom{n}{r} = \binom{n}{n-r}$$







$$f^{(n)}(z) = \frac{n!}{2\pi i}\int_C \frac{f(\zeta)}{(\zeta - z)^{n+1}}\,d\zeta$$



$$m\frac{d^2x}{dt^2} + b\frac{dx}{dt} + kx = F(t)$$

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MATHEMATICS
AND
WOMEN'S CAREERS

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Lauri Steel, Associate Investigator

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(Comments and suggestions from readers are cordially invited.)

MATHEMATICS AND WOMEN'S CAREERS

Preface

Mathematics and Success (meaning, among other things, MONEY)

It's no secret that the income levels of American men and women are grossly unequal. The latest figures from the U.S. Department of Labor show that in 1975 the national median income* was $12,770 for fully-employed men, and $7,531 for fully-employed women. The gap was even greater among people with college educations. In this group, men earned a median income of $17,891 compared to $10,861 for women. [1]

One explanation for these large differences in salaries has to do with the kinds of jobs held by men and women. Males in this country work in a wide range of careers, including the mechanical and technical trades and the higher-paying professions of law, medicine, business management, science, architecture, and engineering. In recent years, increasing numbers of women have begun to enter these fields. But most female professionals are still clustered in a small number of lower-paying occupations such as teaching, nursing, and social work. The extent of this occupational segregation can be seen in many areas. For example, in 1970, only one percent of the engineers, two percent of the computer specialists, sixteen percent of the physical scientists, and twenty percent of the biological scientists were women. [2]

It's important to note that most of these "male-dominated" professions require training in college-level mathematics. The lack of such training is undoubtedly one of the reasons why there are so few women in these fields. According to a 1978 report on high school seniors from the College Entrance Examination Board, about 63 percent of last year's college-bound males had taken four or more years of high school mathematics, while only 43 percent of the females were similarly prepared. [3] Similar findings have been reported by colleges all across the country. Quite simply, this means that more than half of today's young women are reaching college unprepared to take the math courses required for entrance into many of the higher-paying careers!

This situation has created concern among educators and researchers at many levels and recently led the National Institute of Education to fund a special series of studies on the role of mathematics in women's education and career development. This booklet is a product of one of those studies: the Women and Math Project conducted by the American Institutes for Research (AIR) in Palo Alto, California. The basic questions asked by this study were (1) what accounts for the differences between men and women in high school math achievement and participation, and (2) how do these differences affect the development of women's careers?

---

*Median income means middle income, with half the people earning more and half earning less.

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The raw material for this study came from two long-term surveys of American youth. The first of these was Project TALENT, AIR's study of 400,000 Americans who were in high school in 1960 and are now in their early to middle thirties. TALENT's data was gathered during two days of testing in 1960 and in follow-up surveys conducted one, five, and eleven years after the participants finished high school. The data base includes information on abilities, interests, career plans, occupational history, and life experiences up to age 29. A second source of data is the National Longitudinal Study of the High School Class of 1972, conducted by the National Center for Educational Statistics. This information was gathered in surveys conducted in 1972 and one, two, and four years later. A study of more than 23,000 high school seniors, this data base contains information very similar to that found in Project TALENT, except that the occupational histories (being shorter) are not as complete. The similarity of the information in two surveys has enabled AIR's Women and Math Project to make several important comparisons between the characteristics and plans of high school students of the early 1960s and those of the early 1970s.

AIR's Women and Math study provides the primary basis for this booklet, but findings from other studies are also presented. The bracketed numbers scattered throughout the text indicate the sources of the various pieces of information. A complete list of these sources can be found on page 26.

Our hope for this booklet is that it will give a small, creative nudge to the thinking of parents, teachers, counselors, and others who influence young women's educational and career plans. Even more, we hope it will help young women themselves to begin thinking about math whenever they think about the future.

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Chapter One

SEX AND HIGH SCHOOL MATHEMATICS

Some Myths and Some Facts

What on earth does *sex* have to do with *mathematics*? Plenty, it seems, if you consider facts like those we discussed in the Preface, along with some of the popular myths about math. Let's take a look at a few of these myths.

SOME MYTHS ABOUT MATH

- "Boys are naturally better than girls at math."
- "Boys like math better than girls do."
- "Boys *need* to take math. Girls don't."
- "Math is a masculine subject. 'Feminine' girls aren't interested in it."

We call the above statements "myths" because--like most myths--they are explanations for events or situations that are not well understood. Since most myths are mixtures of fiction and fact, it's important to examine them closely to try to find out just what they are made of. Let's look first at the situations that these "math myths" attempt to explain.

SOME FACTS ABOUT MATH

- Beginning in about the tenth grade, or the sophomore year in high school, far more males than females take elective courses in mathematics. Such courses include first- and second-year algebra, geometry, trigonometry, and pre-calculus. Most of these courses are included in the prerequisites for a great many college majors. (See box on page 9 .)

- By the last year of high school, the average math achievement score for males as measured by the Scholastic Aptitude Test is significantly higher than the average math achievement score for females. [4]

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- By the time they reach college, far fewer females than males are qualified to take the calculus or intermediate statistics courses required for such majors as chemistry, physics, biology, pre-medicine, engineering, psychology, environmental sciences, architecture, business management, economics, aeronautics, pharmacy, mathematics, or computer sciences. [3;5]

How can we account for these differences? Do they mean, perhaps, that the "myths" are true, and that math is somehow wrapped up with masculinity? To find out, let's look at each of these myths with an eye toward untangling fact from fiction.

MATH MYTH #1

"Boys are naturally better than girls at math."

The idea that boys are "naturally better" than girls at mathematics is reflected in several fascinating theories. These range from the notion that the male intellect is more "variable" (resulting in more male geniuses as well as more mentally-retarded males), through theories about the effect of sex hormones and other biochemical agents on math ability, to hypotheses about the X-linked male inheritance of certain problem-solving skills. So far, we have found no convincing arguments to support any of these suppositions. (For a critique of this entire field of research, see the reference to Julia Sherman. [6])

There are, however, several ideas about "natural math ability" that deserve some discussion. These arise from the observation that males tend to perform better on tasks involving a process called "spatial visualization," while females tend to do better on "verbal" tasks. [7] Both kinds of skills are important components of "math ability." Males, however, tend to do better on the "spatial" types of problems that occur in such subjects as geometry, while females tend to do better on "verbal" or arithmetic-computational problems.

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While these skills might be inborn, it is equally possible that they are learned. In our society, young males are typically encouraged to participate in such "spatial" activities as building with blocks, playing with erector sets, working with machine tools, and studying mechanical drawing. In contrast, young females usually get far fewer opportunities to develop their "spatial skills."

What does all this mean in terms of Math Myth #1: "Boys are naturally better at math than girls are"? We think it means the myth needs revising, to read as follows:

REVISED
MATH
MYTH #1

> "BY ADOLESCENCE, BOYS ARE BETTER THAN GIRLS AT SOME KINDS OF MATH PROBLEMS."
>
> . . . and, on the other hand, . . .
>
> "BY ADOLESCENCE, GIRLS ARE BETTER THAN BOYS AT SOME KINDS OF MATH PROBLEMS."

Obviously, this "revised myth" needs further exploring--so let's return to another one of the important facts upon which the original myth was based--the finding that boys as a whole get higher twelfth-grade math achievement scores than girls, as a whole. Could this mean that boys are (as the original myth suggested) "naturally better"? If they are, it's not apparent in the early years of school, where many studies have found boys and girls to be equally able in math, [8] and at least one study of third and sixth graders found that girls did slightly better. [9]

It's interesting, then, to learn that even though the sexes appear about equally matched in math ability in the elementary grades, researchers have found that teachers at all grade levels tend to believe that boys do better. When elementary school students themselves were asked who did better in math, the boys stated that boys did better, while the girls said that girls did better. By high school, however, almost one-third of the girls had come to believe that boys did better in math.[8]

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This last finding is especially intriguing when we consider that the differences between the sexes in math achievement among a nationwide sample of ninth graders were found to be very small. [10] The place where real sex differences in achievement did start to show up was after tenth grade, the time when math courses usually become truly elective and (as we've noted before) when more males than females choose to study math. The chart below shows what happened to the average math achievement scores for boys and girls during four years of high school between 1960 and 1963. Clearly, by twelfth grade, boys were doing better in math.

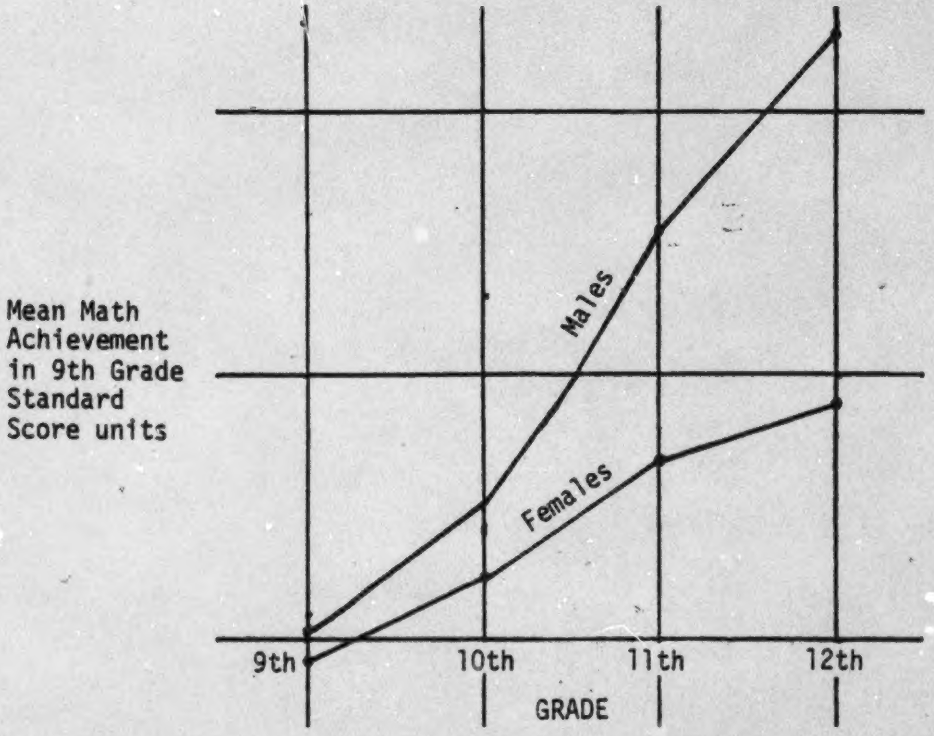

Figure 1. When do sex differences in math achievement occur?

Figure 1 shows the changes in the mean (average) math achievement scores for males and females in the TALENT sample between the ninth and twelfth grades.* (Remember that it's a "picture" of all the students in the sample, regardless of how much math they had studied.)

---

*Project TALENT is a long-term study of some 400,000 Americans who were in high school in 1960 and are now in their middle thirties. Members of the TALENT sample (whose anonymity is guaranteed) were tested and questioned at length in 1960, and again in 1961, 1965, and 1971. The information contributed by this group has been used in more than 100 studies of the relationship between early experiences and the course of adult life.

What does Figure 1 mean in terms of our revised myth? We think it means that we need to add one more sentence to the myth, so that it reads:

SECOND
REVISION
OF MATH
MYTH #1

"BY ADOLESCENCE, BOYS ARE BETTER THAN GIRLS AT SOME KINDS OF MATH PROBLEMS."

. . . and, on the other hand, . . .

"BY ADOLESCENCE, GIRLS ARE BETTER THAN BOYS AT SOME KINDS OF MATH PROBLEMS."

. . . but the fact remains that . . .

"BY THE END OF HIGH SCHOOL, BOYS AS A WHOLE ACHIEVE HIGHER MATH SCORES THAN GIRLS AS A WHOLE."

Here's another chart that relates to this "revised myth." It's a picture of what we found when we compared the mean (average) twelfth grade math achievement scores of a group of males and females who took equal numbers of math courses.

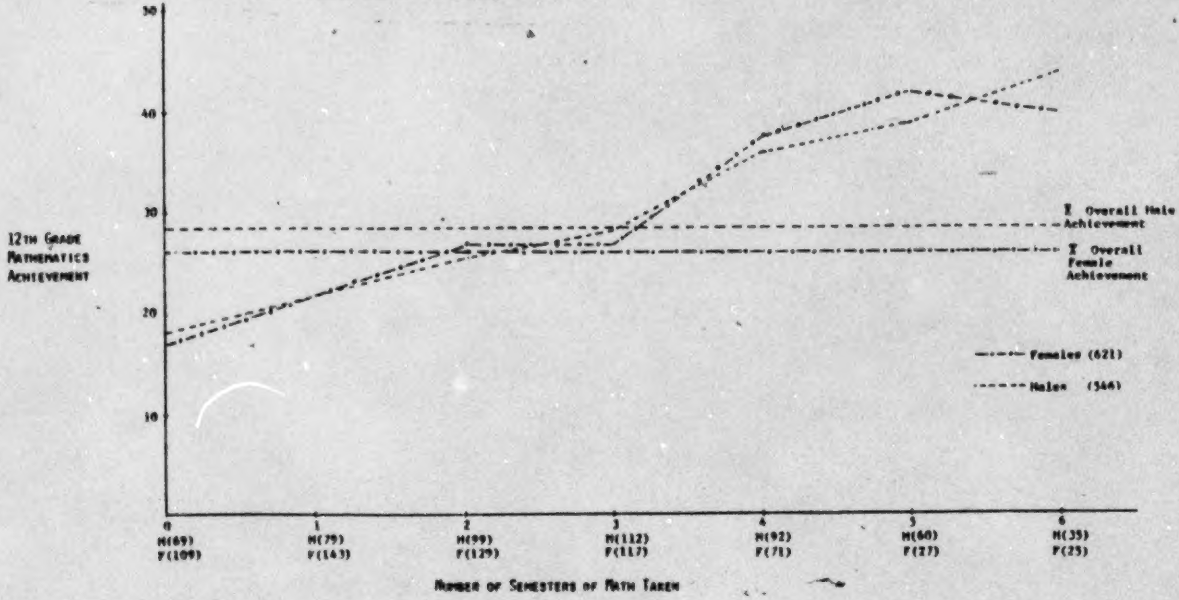

Figure 2. Mean twelfth grade math achievement by amount of math taken.

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When you examine the chart in Figure 2, you'll see that among students who took the same amount of mathematics, the average achievement scores for males and females were very close. (You'll also notice some small differences, such as the slightly higher scores for males who took the smallest and largest numbers of math courses and the slightly higher scores for females who took intermediate amounts of math. These differences are interesting, but they are too small to be statistically significant. In other words, they could simply be the result of "chance.")

What does this chart have to say about our first "math myth"? To us, it says that most of the differences in the twelfth grade scores of boys and girls can be explained by differences in the amount of math that boys and girls have taken. So we'll revise Math Myth #1 once again, so that the last part of it reads as follows:

THIRD REVISION OF MATH MYTH #1

"BY THE END OF HIGH SCHOOL, BOYS AS A WHOLE ACHIEVE HIGHER MATH SCORES THAN GIRLS AS A WHOLE, MOSTLY BECAUSE THEY STUDY MORE MATH."

(Please note our use of the word "mostly." And remember, too, what previous researchers learned about students' and teachers' beliefs about who does best in math. These points will come up again as we explore the other math myths."

MATH MYTH #2

"BOYS LIKE MATH BETTER THAN GIRLS DO."

Now here's a myth that might well explain why more males than females take elective math courses, especially if it could be shown that males like math better from the very beginning. Several researchers have investigated this question--with surprising results. For example, one survey of elementary school students, found that boys and girls liked math equally well. Not only that, but math was the only subject for which there were no sex differences in "liking"! (About 30% of each sex chose math as their best-liked subject and about 28% liked it least.) [8]

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Even more surprising, perhaps, is that the study found a similar situation in high school, where math had become somewhat less popular but was still liked (or disliked) equally by students of both sexes. [8]

These and similar findings throw serious doubt on Math Myth #2 which should probably be revised to read:

REVISED MATH MYTH #2

"BOYS AND GIRLS SEEM TO LIKE (OR DISLIKE) MATH EQUALLY WELL."

If this is so, and if ninth grade boys and girls really do start out about equal in math ability, why do so many more boys than girls go on to take elective high school math courses? Several researchers have suggested that this difference may have less to do with "liking" or initial ability than with the realization by many boys that they will need to take math in order to reach their career goals, [8;11;12]. . . . which brings us to Math Myth #3:

MATH MYTH #3

"BOYS NEED TO TAKE MATH. GIRLS DON'T."

A study of the TALENT sample throws some light on this myth. Although the TALENT participants were not asked how much they "liked" or "needed" mathematics, they were asked a number of questions that could give us some clues about why they did or did not study it in high school. We looked for these clues in many places. In particular, we looked at the results of ninth grade tests of math ability and at the answers to questions about:

- how much education students planned after high school
- how interested students were in mathematics
- how interested students were in math-related careers (careers that require college-level math on the job or in preparation for getting the job
- how interested students were in office work (as opposed to math-related careers)

--plus hundreds of other questions about personality, family background, school and community activities, etc.

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We found that the strongest clues (or "predictors") of how much elective math students would take were (1) their ninth grade math achievement scores and (2) the amount of education they planned after high school. But since boys (as a group) and girls (as a group) were so similar in their ninth grade math achievement and in the amounts of schooling they planned, this didn't tell us why so many more boys chose to take math.

When we looked a little farther, however, we found several clues that did seem to explain the sex difference in math participation. The most important of these, for boys and girls alike, was interest in mathematics and in math-related careers.* In other words, those students who were most interested in math itself or in careers that required college math were the most likely to take high school math. The group of girls who took less math than might be expected on the basis of their ability were those who expressed a strong interest in office work. Similarly, the boys who took less math than expected were those with strong interests in the skilled trades. The unequal numbers of boys and girls in elective math courses could be explained in large part by their differing career interests (and presumably by how much math they thought they would need to pursue those interests).

It seems, then, that Math Myth #3, "Boys need to take math; girls don't," contains a fair amount of fact--at least in relation to our sample of 1960 high school students. But to bring it closer to our findings, let's revise it a little to read:

REVISED
MATH
MYTH #3

"BOYS SEEM TO SEE A GREATER NEED TO TAKE MATH THAN GIRLS DO, BASED IN LARGE PART ON THEIR CAREER INTERESTS."

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*See the box on page 9.

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WHAT IS A "MATH-RELATED CAREER"?

Throughout this booklet we define a "math-related career" as one in which college-level math is required on the job or in preparation for getting the job.

Here are a few of the many college majors that require three or more years of high school mathematics.

Agriculture
*Architecture
*Astronomy
*Biology
*Business Management
*Chemistry
*Computer Science
Dental Hygiene
*Economics
Elementary Education
*Engineering
*Environmental Sciences
Food Sciences
Geography
*Geology
Linguistics
*Mathematics
Nursing
*Optometry
*Pharmacy
Physical Education
*Pre-Medicine
*Psychology
Sociology
*Statistics

*These majors require four years of high school math.

(This information was taken from "The Math in High School You'll Need for College," prepared by the Mathematical Association of America with the cooperation of the National Council of Teachers of Mathematics. For copies of the complete pamphlet, write to: The Mathematical Association of America, 1225 Connecticut Avenue, N. W., Washington, D. C. 20036.

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Among the twelfth-grade students in the TALENT sample, 33% of the boys and 3% of the girls expected to enter math-related careers. And their approach to mathematics seemed to reflect these career interests, with 33% of the boys and 9% of the girls taking four years of the high school math they would need to be prepared for college majors in their chosen career areas.

So far, we have talked mostly about people who were students in the early 1960s. Do students of the 1970s also show a pattern of taking high school math in relation to their career interests? If so, we should expect a tremendous increase in the number of women who take four years of high school math, because the number of high school-aged women planning careers that require college math appears to have more than tripled between 1960 and 1975. [13;14]

We were surprised, then, to discover that in the high school class of 1972, only 8.8% of the males and 3.4% of the females had taken four years of high school math. A decline of almost three-quarters for the men and about two-thirds for the women! (See chart on page 11.)

"BOYS SEEM TO SEE A GREATER NEED TO THE MATH THAN GIRLS DO, BASED IN LARGE PART ON THEIR CAREER INTERESTS."

Evidently the "Revised Math Myth #3" that seemed to fit high school students in 1960 no longer fits the students of the 1970s, whose participation in math courses does not relate realistically to their expressed career interests. Somehow, today's students--males and females alike--do not behave as though they were getting the message about the relevance of math.

We don't know why this is happening. Other researchers will certainly want to look into a variety of possible factors, like lowered standards for high school graduation (at the same time that many colleges are tightening the requirements for many majors), the relevance of career counseling programs, and many other subjects that are outside the scope of this booklet.

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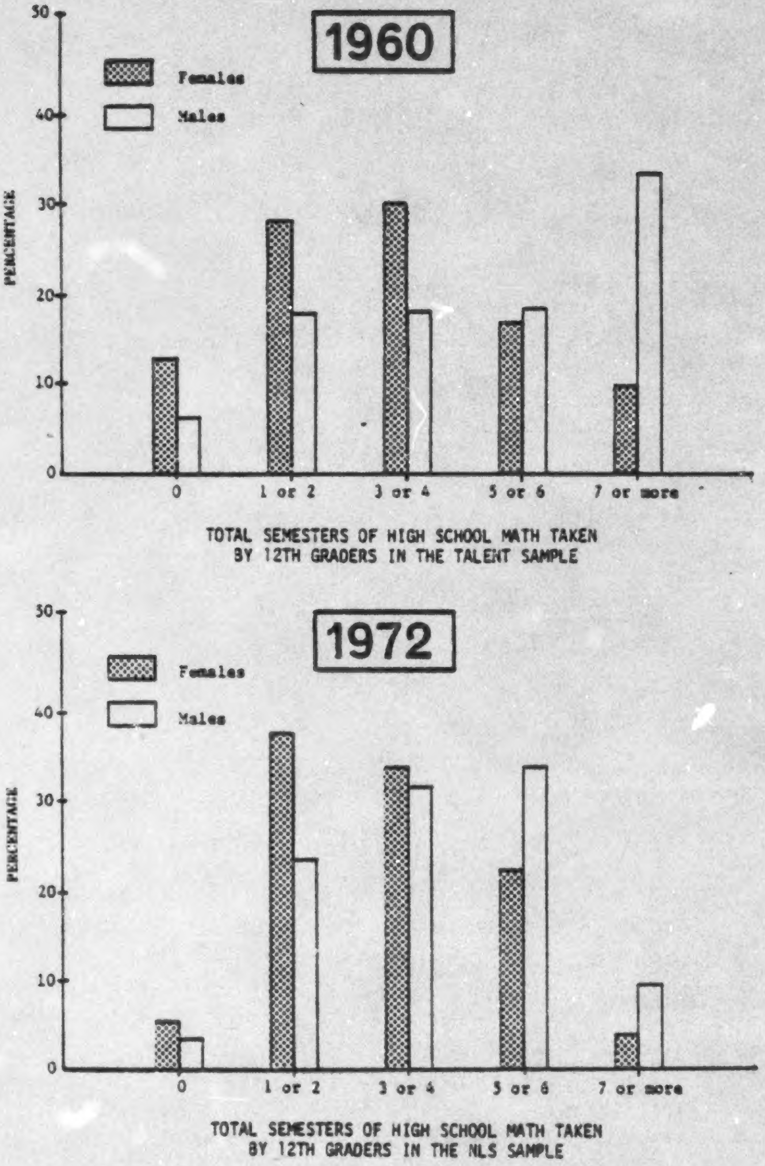

Figure 3. Changing patterns of math course-taking among high school seniors between 1960 and 1972.

(Note the increases, particularly among males, of students taking two or three years of math and the decreases for both sexes of students taking four years of math or no math at all.)

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What these findings mean in terms of our "math myths" is that we need to look for some factors besides abilities and career interests to explain why only about half as many women as men take four years of high school math.

And this brings us to MATH MYTH #4:

MATH MYTH #4

"MATH IS A 'MASCULINE' SUBJECT."

Mathematics, of course, has no gender. And yet--next to "shop" courses, home economics, and tackle football--it's probably the most sex-stereotyped of all high school subjects. The question of how it got to be that way has occupied many researchers--and their findings make it clear that the sex-stereotyping of math is anything but a simple matter. Children, apparently, do not think of math as a "masculine" subject until they reach adolescence. [15] Even in high school, girls deny that math is "for boys," and yet they act as though it were "not for girls" by avoiding math courses. [11;15;16] Hundreds of ideas have been offered to explain this "math avoidance syndrome." Here are a few of them:

- Girls may model their behavior after their "verbally-oriented" mothers rather than after their "quantitatively-oriented" fathers. [7] They may also see too few examples of women whose career success is related to success in math. [17]

- Girls may actually be motivated not to succeed in traditionally "male" areas such as mathematics and math-related careers. [18]

- Teachers may contribute to the notion that math is "for males," by believing (without evidence) that boys are better and by treating male and female students differently in class. [8;16;19]

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- School counselors may be discouraging rather than encouraging girls to take math [12;20;21]

- The social and economic "climate" in some schools--particularly the more affluent ones--many lead to the stereotyping of math as a "male" subject. [22]

- Math textbooks may promote the "male" stereotyping of math by showing males in active roles and by phrasing problems in terms of typically "masculine" activities [23;24;25] and math tests themselves may be sexually biased in the way they select and present problems [16;26;27]

- Girls may--as early as grade school--be less confident of their math ability than boys are, even when they perform equally well. [28;29;30]

- Girls may simply be unaware that math is an important door-opener to many careers besides the strictly scientific ones.

Clearly, there seems to be no single reason why so many girls avoid math. The best we can do with the fourth math myth at this point is to revise it to read:

REVISED MATH MYTH #4

"MANY WOMEN TREAT MATH AS THOUGH IT WERE A 'MASCULINE' SUBJECT."

. . . and, on the other hand, . . .

"A SMALLER NUMBER OF WOMEN TREAT MATH AS THOUGH IT WERE APPROPRIATE FOR WOMEN."

Let's take a closer look at these two groups of women. What are some "typical traits" of the young woman who takes math and does well in it? And equally important: What are some typical traits of the

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young woman of equal ability* who avoids the study of math? An analysis of data from the TALENT sample uncovered many interesting answers to both of these questions. Here are some of them:

The "typical" girl who took elective math was likely to have:

- fairly affluent parents who expected her to go to college
- a father who discussed her career plans with her
- a mother who was active in the PTA or similar organizations
- high levels of knowledge in areas ranging from home economics to law, sports, and biological science
- more interest in math itself and in math-related careers than in office work
- leadership qualities and an above average level of self-confidence
- little concern with earning a living immediately after high school
- a school program that included standardized testing and an accelerated science curriculum

In contrast, . . .

The equally able girl who avoided math was likely to have:

- less affluent parents
- less self-confidence
- more interest in office work than in a career that involved mathematics
- more discussions of her future with her school counselor than with her father
- more concern with earning a living right after high school

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*As measured on a test of math achievement in ninth grade.

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The same analysis also enabled us to create profiles of two "typical" boys who provide an interesting contrast to our "typical" girls--as well as to each other.

The "typical" boy who took elective math was likely to have:

- highly-developed "spatial skills" and an aptitude for table-reading
- a "scientific attitude" (essentially a belief in lawfulness along with considerable information about electricity and electronics
- little inclination to participate in sports, hobbies, or extracurricular activities
- considerable information about foreign travel*

In comparison, . . .

The equally able boy who avoided math was likely to have:

- more interest in the skilled trades than in math or math-related careers
- more discussion of his future with his school counselor during ninth grade
- more interest in hobbies, sports, and extracurricular activities--particularly those that might be stereotyped as "male" (e.g., hunting, fishing) or "female" (e.g., opera, ballet)
- plans for a "higher prestige" career than that planned by the boy who took more mathematics

There is, of course, no such person as the "typical math-taker" or "typical math-avoider" of either sex. Rather than giving us pictures of individual students (whose personalities were every bit as unique and varied in 1960 as they are today), these profiles show us

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*We don't know what this means in terms of math, either!

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some of the traits that were more likely to show up in one group of students than in another. Nonetheless, these profiles raise some important questions for parents, teachers, counselors, and students, which will be discussed at some length in the next chapter.

In the next chapter, also, we will take a look at the role of math in the careers of some anonymous but real people in the TALENT sample, between their last year of high school and the age of 29.

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Chapter Two

HIGH SCHOOL MATH AND CAREERS: DOES MATH REALLY MATTER ?

The answer to the question is, "Yes. Math really does matter in a great many careers." When we looked at the careers of a group of men and women in the TALENT sample,* we discovered that high school math was a vital factor in determining whether or not students entered certain kinds of occupations. Furthermore, math skills made a difference in the way that students developed their careers throughout the entire period between high school and age 29. As we noted in the first chapter, about 33% of the twelfth grade boys and 3% of the twelfth grade girls were planning math-related careers in 1960. By 1971, however, less than 20% of these males and 10% of the females had actually succeeded in carrying out their career plans.

Why such a small percentage of "math-career achievers"? Apart from the obvious answer that it's natural for young people to change their life plans as they mature, there's another explanation: For the high school seniors who planned math-related careers in 1960, two crucial factors in whether or not they achieved their careers were (1) the development of math skills in high school, and (2) the early formation of career plans that encouraged the development of such skills.

Put simply, the men and women who succeeded in entering such math-related careers as chemistry, engineering, medicine, and architecture had much higher twelfth grade math scores than a comparison group of people in other kinds of careers. Almost without exception, these "math-career achievers" had been planning for some kind of math-related career since the twelfth grade or earlier and tended to go straight into college right after high school. The extremely small number of people (3% of the men and 0.2% of the women) who weren't planning math-related careers in high school but switched into them later were also people with extra-high

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* The group discussed in this chapter was the "12th grade cohort," approximately 12,000 young men and women who were first tested as high school seniors in 1960 and who also responded to follow-up questionnaires in 1961, 1965, and 1971.

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math scores in twelfth grade. (For a glimpse of the one woman in our sample who made the switch to a math-related career, see the profile of "Martha" on page 24.)

Not only did we find far more males than females in math-related careers, we also found large differences in the levels of education attained by men and women during the years between high school and age 29. In the twelfth grade, more males than females were planning to go to college. Five years after high school, similar proportions of men and women had actually finished college (26% and 22%, respectively), but roughly twice as many men as women had gone on to graduate school. By the time these people were 29, far more men than women in the group had advanced degrees.

Even among men and women with equal amounts of education, males were vastly more likely to be in math-related careers. Of the people with bachelor's degrees, 15% of the men but only 1% of the women were working in math-related careers. Similarly, among people with advanced degrees, only 3% of the women (compared to 23% of the men) had math-related careers.

What was it that enabled this tiny fraction of women to reach their career goals?

Hoping for some insight into this question, we took a detailed look at the 45 women in our twelfth grade sample who were in math-related careers either five or eleven years after high school. Here is a "profile" of the group as a whole:

- High school math achievement. As a group, these women had impressive twelfth grade math scores--an average of 42.6 points out of a possible 54. (The overall average for twelfth grade boys in the sample was 26.6. The overall average for girls: 22.1. [10]) The highest score, achieved by a future physicist, was 53. The lowest was 25--achieved by a future biologist with only three semesters of high school math.

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- Educational achievement. At the age of 29, almost one-third of the women had doctoral degrees: nine were M.D.s, three were Ph.D.s, and two were doctors of veterinary medicine. Nine of the group had master's degrees, and 22 others had bachelor's degrees.

- Occupational choices. As indicated above, the most popular career was medicine: one woman was a opthamologist, three were pediatricians, three were psychiatrists, and two were medical researchers. The second most popular career was chemistry, followed by pharmacy, biology, mathematics and statistics, and clinical sciences, in that order.

  Only two women in the group had gone into engineering, and one of them was a housewife at age 29--with no intention of returning to her former career. Two of the three other housewives planned to resume their work or their advanced educations as soon as their children were in school. Several other women in the group were mothers of young children, but continued to work outside the home either full- or part-time.

"Jane"--Math Teacher Turned Actuary

Unlike the women in our other profiles, whose educational attainments generally paralleled those of their parents and friends, Jane had--and achieved--her own set of goals.

The youngest of five children, Jane had parents whose education ended with high school. Most of her friends did not anticipate going to college. But Jane, a confident, mature, well-adjusted teenager, was very definite in her plans for college and a career as a high school teacher.

Jane's high school friends may have seen her as rather "bookish," for she had little interest in extracurricular activities, preferring to pursue her studies and obtain high grades in all of her subjects, including math. During these years, she discussed her career plans may times with her parents, her friends, and her school counselor. And, whether or not she received support for her plans, she went ahead with them.

At the end of her first year of college, Jane was getting A's in mathematics and had upped her educational plans to include a master's degree in the subject. She achieved this goal in 1967, at which time she was already teaching high school math.

By 1971, however, Jane was in a different career. As an actuary, she was using her math skills to compute statistical probabilities for an insurance company. Still single, she declared her satisfaction with her job and with her salary of $9,000 a year--which she earned by working only ten hours a week!

We can only guess at Jane's reason for veering from her original career course. Perhaps she grew tired of working with teenagers. Or perhaps she valued time more than she did money, choosing the freedom to pursue other interests that goes with a part-time job. Whatever her reasons for entering her second career, Jane planned to continue in it indefinitely--and credited her early math training with making it possible.

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"Karen"--Physicist at Age 29

Karen is in many ways a "perfect" example of a popular stereotype: the smart, single-minded, not overly-sociable person who becomes a scientist. Of all the women in our sample who planned or achieved math-related careers, Karen had the highest 12th-grade math score: 53 points out of a possible 54! Even in elementary school, Karen had hoped to become a physical scientist, and her dedication to this career plan apparently never wavered.

The daughter of a skilled worker and a housewife--both of whom had attended college without graduating--Karen was already planning for an advanced college degree while still in 12th grade. During high school, she participated moderately in extracurricular activities and rated herself quite mature but not very sociable, not very tidy, and low in self-confidence and leadership. Her level of interest in physical science, engineering, and math was exceptionally high. She scored 40 out of 40 on this scale!

At the end of her first year of college, Karen was getting mostly A's in mathematics and had raised her educational goal to include a Ph.D. in physics. When TALENT contacted her again, in 1965, she was in her first year of graduate school, and supporting herself by teaching.

In 1971, when Karen was approximately 29 years old, she was earning $15,000 a year as a physicist. (She had finished her postgraduate education in 1967 with a master's degree and expressed no intention of returning to school.) Looking back at her life experiences, from the threshold of her thirties, Karen said she had "no regrets." Single, she enjoyed her work very much and thought her current job fit very well into her long-range career plans. She gave her high school education (in which her four years of math had played a big part) a top rating for its value in preparing her for her future career.

Impersonal as they are, these collected statistics suggest that this was a group of unusually able and determined women. To give you a glimpse of some of their qualities, we have constructed "profiles" of several real (but anonymous) women--which you will find in these boxes. Reading these, you will see that women who go into math-related careers are very much "un-alike." Still, when we consider some of the similarities that emerge from these profiles--along with the findings presented earlier in this booklet, several important facts about math and careers become clear. They are as follows:

1. High school math skills (developed through participation in elective math courses) are vitally important in the development of math-related careers.

2. Early career plans are vitally important both in the development of math skills and in the development of math-related careers.

3. Even when a math-related career is not specifically planned, high school math skills are vital for keeping a wide range of career options open.

What is the practical significance of these statements for teachers, counselors, parents, and students? In everyday language, we think it

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means that in future efforts to increase the math participation and achievement of women, special attention should be paid to:

- *Timing*. As we have seen, sex differences in math achievement increase most sharply after tenth grade (a major turning-point in decisions about how much high school math to take.) Considering the very significant differences in interests that already exist between boys and girls in ninth grade, it appears that effective career education needs to begin very early. (It's encouraging, however, to note that later factors such as standardized testing and accelerated science curricula in high school also tended to increase math participation and achievement by girls.)

"Edith"--Pursuing a Career in Earth Sciences

Edith, who became a geologist after at least two changes in career plans, represents the kind of woman who takes pains to establish herself professionally before starting a family. As a senior in high school, Edith had an excellent math achievement score even though she claimed to get mostly B's and C's in the subject. At this point, she was tentative in her plans for a liberal arts major in college, followed by marriage and at least three children. She had no doubts, however, about *going* to college, as she was a member of a family who expected their children to become college graduates. Edith's father, a government official who took a strong interest in his children's education, was influential in helping Edith set her career goals.

During her first year of college, however, Edith's interests moved from liberal arts toward medical technology--a new goal that she later abandoned. Five years after high school, Edith had a bachelor's degree in physical science, a job as a research technician, and plans to become a geologist.

This latter goal is the one that she reached. At the threshold of her thirties in 1971, Edith had become a geologist after returning to school for some work toward a master's degree. She found her work both satisfying and challenging, but expressed her willingness to put it aside at a later date for another career she still planned--as a housewife and mother.

- *Targets*. Since high socioeconomic status (essentially "affluence") was found to be related to math participation among girls, teachers and counselors should give special encouragement to high math-ability girls from lower status families. Other possible "targets" are girls with high ability but low career or educational aspirations, girls with low levels of self-confidence, and girls with little knowledge about the relationship of math to careers.

  The fact that fathers' characteristics and daughters' math participation were closely linked suggested that young women who do not have the opportunity to discuss their career plans with their fathers might also be "targets" for counseling.

"Renata"--Who Followed Math into the World of Computers

Renata's career is an excellent illustration of the way a young women with an early aptitude for math can develop her skills in the subject and eventually pursue a career in a closely related field.

Renata, who grew up surrounded by a "library" of books, was the oldest daughter of well educated, foreign-born parents who were fluent in several languages. Although Renata's father was employed as a laborer in 1960, he had a doctorate from a European university. (He may have been doing the most expedient thing while earning his U.S. credentials for his chosen profession.) Renata's mother, a college graduate, had worked many years in a supervisory position, providing a career role model for her daughters.

As a 12th grader, Renata was a mature, sociable girl with leadership ability--even though she saw herself as slightly lacking in confidence. She participated in a few extracurricular activities but concentrated hard on her studies, receiving A's in mathematics as well as in most of her other courses. At this point in her life, she expected to go to college and become a biological scientist (but stated that she'd like to become an artist or entertainer). Her career, she imagined, would be disrupted little--if at all--by her intention to marry at 21 or 22.

A year after high school, her primary interest still in laboratory sciences, Renata was in college, with plans for a Ph.D. in chemistry. Over the next four years, however, she changed her direction. By 1965, Renata had a bachelor's degree in mathematics and was employed as a mathematician. She had not received her planned-for Ph.D., possibly because she had also carried out her plan to marry at age 22.

Six years later, in 1971, Renata had changed careers within the general field of mathematics and was now working as a computer programmer. Still happily married, she expressed no regrets with her career choice or with her annual salary of $15,876 (a fairly high salary for a woman in 1971, and the second highest salary earned by a woman in a math-related career in the TALENT sample).

"Ellen"--A Medical Writer Who Hopes for an M.D.

It seemed important to write about Ellen, a bright woman who upgraded her goals as she grew older and whose story reflects the "balancing act" so often required of the woman who combines marriage and childrearing with a career.

The youngest of seven children in a farmer's family, Ellen had "fairly indefinite" plans in 12th grade for an advanced college degree and a career as a biological scientist--a goal that may well have been encouraged by her mother, who worked as a nurse. At this time, Ellen also expected to marry at 23 or 24 and to have three children. With four years of high school math, high grades, and an exceptionally high academic aptitude, Ellen was well-equipped to reach her career goals in spite of the fact that she was not very confident.

By the age of 23, Ellen had reached two of her goals. Newly married, she had a bachelor's degree in zoology and was a part-time graduate student working part time in a clinical laboratory. Her educational plans at this time were for a master's in biology and a career as a clinical scientist.

When Ellen was contacted again in 1971, however, she had entered a different phase of her life. Now the mother of two small children, she was employed ten hours a week as a medical writer--a secure job that she "rather liked" but did not find very challenging. At the age of 29, Ellen expressed some indecision about continuing as a medical writer, for her career plans were still evolving, and she was considering an eventual return to school with the goal of becoming a physician. If her later career course paralleled that of other early achievers in math, it's likely that Ellen has her M.D. today.

- Replacing Anxiety with Confidence. Math anxiety, or the "I can't" syndrome that often goes along with the avoidance of math courses [5] needs to be attacked from all fronts. Some encouraging steps toward reducing math anxiety have been reported from special classes and "clinics" for women that combine supportive counseling with remedial work. In view of our findings about the role of self-confidence in

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the math achievement of women, other kinds of programs that help young women to become more confident should also improve their performance in math.

"Beth"--An Ophthalmologist Who Worked Her Way Through School

Beth is an example of a professional woman whose mother was also a professional--a high school science teacher. Although Beth's mother had a master's degree, her father, an owner of a small business, did not finish college. Beth's family was fairly well off, as were the families of many of the women who excelled in math. Her family was also well-educated and well-read. It was always expected that Beth would graduate from college.

Earning top grades in math and science, as well as in English and foreign languages, Beth as a senior in high school anticipated becoming a biological scientist. She described herself as very sociable, a leader, but a bit low in self-confidence. Her strongest desire was to be a physician. Parents, counselors, and friends were very helpful to the aspiring young woman in encouraging her to pursue the career of her choice. She did indeed graduate from college with a biological science major, and entered medical school the following year.

In order to do this Beth found it necessary to supplement her parents' financial backing with scholarships and a part-time job as a lab technician. She evidently found it very rough going at this time of her life--attending classes, studying, working--for in the TALENT 11-year follow-up, she expressed regret at having had to work her way through school.

Unlike the other women in our profiles, Beth did report some dissatisfaction with her job in 1971. Perhaps she found that her $12,000 a year income was not enough to live on after covering the costs of setting up an expensive practice. She had anticipated earning a good living at challenging work, while maintaining a certain amount of freedom. Although Beth was somewhat discouraged at age 29, it is probable that with the perseverance she had already demonstrated, she is now well established in a satisfying career.

- **Increasing Math Awareness**. This means appreciating the importance of developing math skills early, and remembering the relevance of math to many careers besides the purely scientific ones. Everyone should get involved in this process.

  For parents increased "math awareness" means:
  - paying attention to the early career interests and math skills of daughters as well as of sons.
  - providing girls as well as boys with opportunities to develop their "spatial" skills through such activities as building with blocks or erector sets and working with tools.
  - encouraging girls not to limit their occupational choices, but to consider the full range of careers that might someday interest them.

  For teachers increased "math awareness" means:
  - noticing who is getting the most attention in math class, the high-achieving male student or the girl who needs help? (It's been found that even high-achieving girls get little attention in math classes.)

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- paying attention to the way mathematics is presented in classroom discussions, textbooks, and tests. (If math is coming across as being "for boys," you might consider making some changes.)
- considering ways of reducing "math anxiety" among students of both sexes.
- examining your own attitudes about who "needs math" and which sex does better in it.

For counselors, increased "math awareness" means:

- noticing the importance of tenth grade as the water-shed decision point for elective high school math and urging able students to continue their math training beyond this point no matter what careers they presently envision.
- remembering the "power of the raised eyebrow" when discussing career plans with young women. Keep in mind that there are many subtle ways of squelching a student's ambitions.

For students, increased "math awareness" means:

- keeping your career options open by taking at least three years of high school math. Remember that math may be the key that unlocks a future you haven't yet imagined.

"Martha"--Civil Engineer at Age 29

Martha's story is especially interesting, for she is one of only two women in our small sample who ended up in a math-related career after planning a very different sort of future in high school.

In 1960, Martha expected her future career to be "housewife" (although she indicated that the career she would most like to enter was law). Although she saw her life goal as a domestic one, Martha planned to attend four years of college--an expectation that her father, a factory foreman, and her mother, an artist, shared with her. In preparation, she had taken four years of high school math, with grades of mostly A and B. Her interests in physical science, math, and engineering, however, were only "middling."

By the end of her first year of college, however, Martha had switched her career goal to civil engineering and intended to study for a master's degree in the subject. She proceeded to do exactly what she intended, graduating from college in 1965, entering graduate school that same year (while working as a graduate assistant in the engineering department), and receiving her master's degree in 1967.

By 1971, Martha was employed full time as a civil engineer, earning $13,200 a year. She not only liked the work, but said she intended to work in the field "indefinitely." Now 29, Martha was still single. Her early expectation of becoming a "housewife" (not to mention her dream of becoming a lawyer) seemed clearly to be things of the past.

If only we had a crystal ball, we might be able to learn what happened during Martha's first year of college that caused her to change her life plan so completely. A late-night "rap session" in the college dorm? An exciting instructor? A chance meeting with a woman engineer? A disillusioning love affair? Unfortunately for us, we can never know. What we can say with considerable certainty is that Martha's high school math training and achievement were crucial factors in enabling her to move into an interesting career that she had not even considered while in high school.

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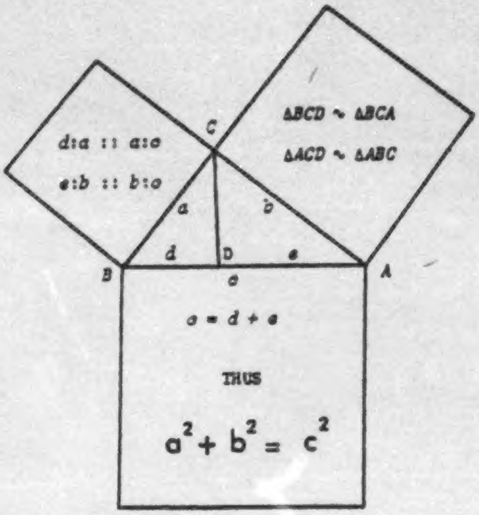
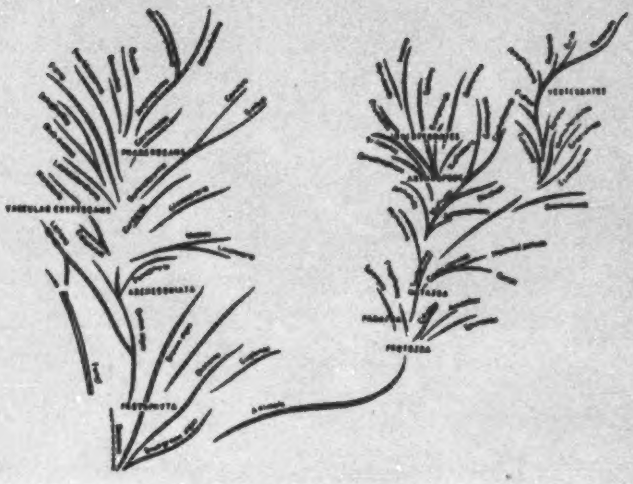
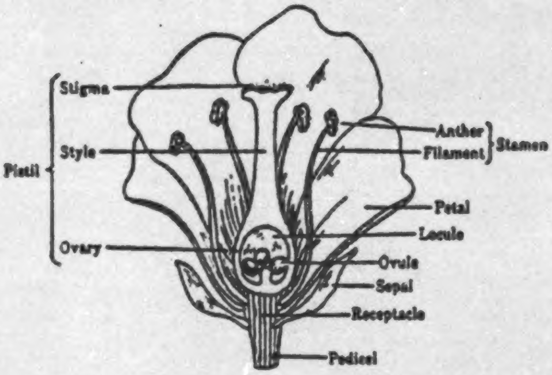
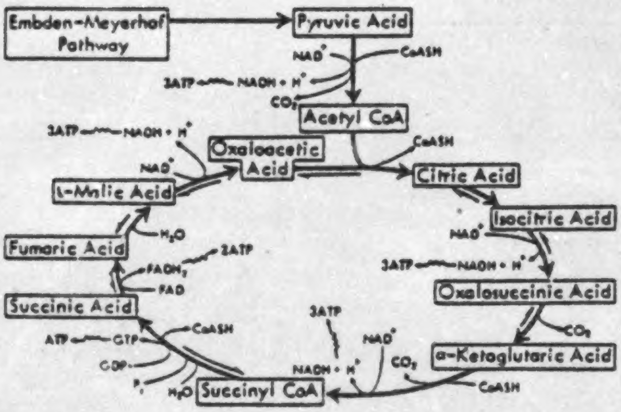




$$\nabla\cdot \mathrm{D} = 4\pi\rho$$
$$\nabla\times \mathrm{H} = \frac{4\pi}{c}\mathrm{J} + \frac{1}{c}\frac{\partial \mathrm{D}}{\partial t}$$
$$\nabla\times \mathrm{E} + \frac{1}{c}\frac{\partial \mathrm{B}}{\partial t} = 0$$
$$\nabla\cdot \mathrm{B} = 0$$





$$\epsilon_0 \oint E\cdot dA = \sum q$$
$$\oint B\cdot ds = \mu_0 \int J\cdot dA + \mu_0 \epsilon_0 \frac{d}{dt}\int E\cdot dA$$
$$\oint E\cdot ds = -\frac{d}{dt}\int B\cdot dA$$
$$\oint B\cdot dA = 0$$